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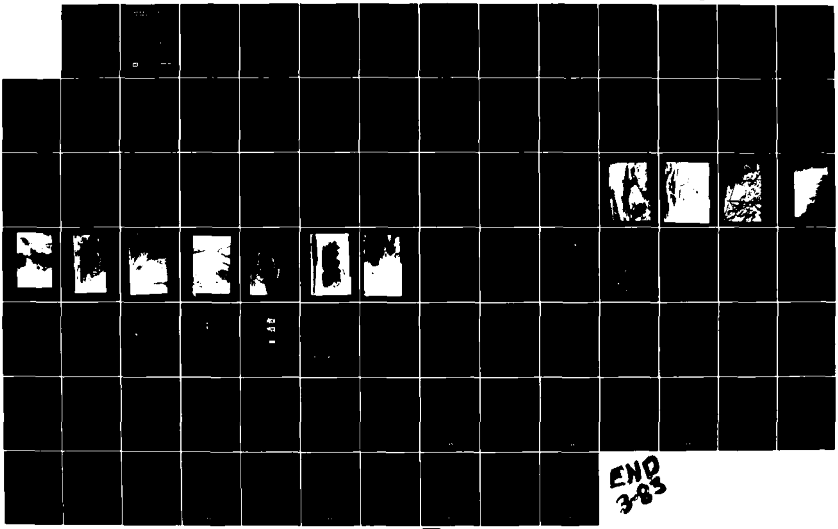

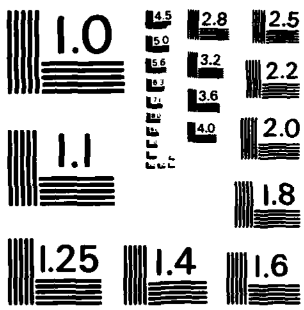

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EMBANKMENT CRITERIA AND PERFORMANCE REPORT

NOVEMBER 1981

FALL RIVER BASIN

COLD BROOK LAKE, SOUTH DAKOTA

US Army Corps
of Engineers
Omaha District

Embankment Criteria and Performance Report

<u>COLD BROOK DAM AND LAKE</u>
Cold Brook, Fall River Basin, South Dakota

Prepared For
Office, Chief of Engineers
U. S. Army
by
U. S. Army Engineer District, Omaha

Partial

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PERTINENT DATA

Location of Project

Fall River County, South Dakota, on Cold Brook, Fall River Basin, 1.25 miles north of the confluence of Cold Brook and Hot Brook.

Type of Project

Flood control and water conservation reservoir.

Purpose

To furnish protection from flood damage to Hot Springs, South Dakota, and vicinity and water conservation for recreation and protection of fish and wildlife.

Authority

Flood Control Act, Public Law 228, 77th Congress, 1st Session, approved 18 August 1941.

Drainage Areas

Cold Brook at Cold Brook Dam, square miles	70.5
Fall River at Hot Springs, square miles	137
Fall River at mouth, square miles	164

Design Storms

Spillway - (150% of Ft. Meade Storm*) average, inches	9.24
Reservoir - (85% of Ft. Meade Storm*) average, inches	5.23
Infiltration	
Spillway design storm - inches per 15 minutes.	0.20
Reservoir design storm - inches per 15 minutes.	0.28

Initial loss, inches	0.40
Runoff (volume) acre-feet	
Spillway design flood	24,250
Reservoir design flood	8,347

*The storm of 12-13 June 1907 at Fort Meade, South Dakota is considered representative of the most severe thunderstorm type cloudburst that may occur in the Black Hills region.

Reservoir

Elevations, area, and capacities

Feature	Elevation (Feet)	Reservoir Area (Acres)	Reservoir Capacity Acre-Ft.	Equivalent Runoff** (Inches)
Top of Dam	3675.0			
Pool at maximum stage with surcharge	3667.2	279	10,800*	2.88
Reservoir design storm with surcharge	3651.4	198	7,200*	1.92
Spillway crest	3646.5	179	6,260*	1.67
Lower Lip of trashrack	3600.0	58	1,200	0.33
Conduit intake crest (conservation pool)	3585.0	36	520	0.14

*Includes conservation pool
**Not cumulative

Inflow - peak - reservoir design storm, c.f.s.	32,861
Storage - reservoir design storm, acre-feet	6,680

Dam

Type - Rolled fill earth embankment with protective riprapping on the slopes

Maximum height above streambed, feet	130
Top length, feet	925
Top width, feet	20
Base width, feet	765

Spillway

Type - Uncontrolled sharp-crested weir spillway with a triangular cross section

Crest length, feet	200
Crest elevation, feet	3646.5
Gates	None
Length from crest to end of downstream excavation, feet	320
Spillway design storm (peak) maximum inflow, c.f.s.	95,708
Spillway design storm (capacity) maximum outflow, c.f.s.	80,600

Outlet works

Type - The outlet works consist of the following: An uncontrolled circular concrete intake structure with controlled small pipes for draining the conservation pool; a concrete conduit structure that passes beneath the dam; a concrete stilling basin having baffles and an end sill followed by a rock and gravel lined section of channel.

Number of outlets	One

Outlet works capacity, c.f.s.	
Design discharge of ports with water surface at elevation 3600.0	250
Design discharge of conduit with water surface at elevation 3610.0	1,230
Maximum design discharge of conduit (reservoir design storm)	1,540
Maximum design discharge - conduit and spillway (reservoir design storm)	8,000

Inlet Structure

Type - Circular free-standing reinforced concrete tower structure with inlets at two elevations	
Crest elevation of four ports, feet	3,585.0
Crest elevation of bell-mounted inlet, feet	3,600.0
Top of tower elevation, feet	3,618.75
Height of top of tower from bedrock, feet	74.0
Outside diameter of bell-mounted inlet, feet	18.0
Total area of opening of the four ports, square feet	14.4

Conduit

Type - Circular reinforced concrete conduit	
Inside diameter, feet	6.67
Length, feet	907.0

Stilling Basin

Type - Reinforced concrete basin with baffles and sill	
Length, feet	105.0
Width at end of first 65 feet, feet	43.6

Width at end of stilling basin, feet	50.0
Number of baffles	13
<u>Rock and Gravel Lined Channel Section</u>	
Length, feet	55.0
Width, bottom, feet	50.0
<u>Earth Outlet Channel</u>	
Length (approx.), feet	675.0
Bottom width, feet	50.0

All elevations in this report are referred to mean sea level, North American datum, 1929 General Adjustment, U. S. Coast and Geodetic Survey.

1. Introduction.

1.1. Purpose of Report. The purpose of this report is to provide the significant information needed by engineers to (1) familiarize themselves with the project (2) reevaluate the embankment in the event unsatisfactory performance occurs and (3) provide guidance for designing comparable future projects.

1.2. Authorization and Purpose of the Project. Cold Brook and Cottonwood Springs Dams, along with channel improvements of the Fall River through the town of Hot Springs, South Dakota, was authorized by the Flood Control Act approved 18 August 1941 (Public Law 228, 77th Congress, 1st Session). The primary purpose of Cold Brook Dam is flood control, however, it also provides recreational and fish and wildlife benefits.

1.3. Project Location and Description. Cold Brook Dam is located in Fall River County, South Dakota, on Cold Brook Creek. The centerline of the dam is a mile and a quarter north of the confluence of Cold Brook and Hot Brook Creeks which unite to form the Fall River at the north edge of the town of Hot Springs, South Dakota.

Cold Brook Project works consist of a zoned earthfill dam, an ungated sharp crested weir spillway and an ungated circular concrete outlet structure. Also, three 12-inch gate valves and pipes are provided in the outlet structure to permit draining the conservation pool. Plates 1, 2 and 3 show a general plan of the project and typical cross sections of the dam. Plate 4 shows the details of the emergency spillway, and Plates 5 and 6 show the details of the outlet works.

1.4. History of Project Design. Several sites were investigated to determine the most practicable location for a dam to control the flood runoff from Cold Brook Creek. The availability of suitable materials for random and impervious fill borrow material at the dam site, the existence of a suitable natural spillway site, and the availability of satisfactory rock at the site for spalls, riprap, and concrete aggregate were among the factors which led to the selection of the dam site at the present location. The first comprehensive subsurface investigations were initiated in January 1944. Additional investigations were made in 1949 and 1950 just prior to construction.

Publications which pertain to the project design are listed below.

Definite Project Report	(July 1944)
Analysis of Design Outlet Works	(December 1945)
Analysis of Design	(April 1946)
Definite Project Report Supplement A	(June 1949)
Analysis of Design	(May 1950)

1.5. History of Construction Contracts. The project was constructed by Northwestern Engineering Company of Rapid City, South Dakota, under Contract No. DA-24-016-eng-64, awarded 6 June 1950. The project was completed and accepted on 8 May 1953 for a total contract cost of $1,202,000.

1.6. Significant Operational Events. Since completion, the project has not been tested by a significant pool. Normally, the pool level elevation is 3580 and has only approached the elevation of the drop inlet (3585) twice.

2. Foundation Conditions.

2.1. Foundation Explorations.

2.1.1. Preliminary Investigations. Subsurface explorations at the dam site were commenced in January 1944. At that time, 18 small diameter (NX cores) holes were drilled in the vicinity of the dam and spillway (locations of the holes are shown on Plate No. 7 and logs of the borings are shown on Plates 8, 9, and 10). In addition, 25 auger and churn drill holes and five test pits were put down in the valley alluvium for a distance extending 3200 feet upstream from the axis of the dam to delineate the volume and classify the type of materials present.

2.1.2. Supplementary Investigations. The original borings at the dam site disclosed that the bedrock beneath the valley consisted of brecciated and fractured sandy limestone containing open joints and minor cavities. Since it was felt that this condition might seriously effect the integrity of the dam and may result in possible piping and undermining of the structure, it was requested by the Office, Chief of Engineers that additional borings be made across the valley along the centerline of the proposed cutoff trench with the view of determining whether water passages of a sufficiently large magnitude to cause piping existed. The borings would also serve to more fully delineate the configuration of the bedrock beneath the cutoff trench. In compliance with the above request, 17 NX holes were drilled at the site. Drilling started in December 1949 and was completed in February 1950. Nine of these holes were drilled along the centerline of the

cutoff trench and eight were drilled along the conduit centerline. The locations of these holes are shown on Plate No. 7, and the logs of the holes are shown on Plate 9.

2.2. Geology.

2.2.1. Regional Geology. Cold Brook Creek is situated on the southeastern slope of the mountainous uplift known as the Black Hills. This uplift is an irregular dome, somewhat ellipsoidal in configuration, with the longer axis extending approximately 125 miles in a northwest to southeast direction and the shorter axis extending 50 miles in a west to east direction. The Black Hills dome stands out in bold relief above the general level of the surrounding great plains area. The uplift has been brought about as a result of the large scale orogenic movements originating in the Tertiary epoch and resulting in the formation of the present Rocky Mountain chain of which the Black Hills of South Dakota constitutes an eastern outlier. The core of the uplift is comprised of a mass of granite and this core is surrounded by a series of pre-Cambrian crystalline rocks and a nearly complete sequence of sedimentary formations ranging in age from late Cambrian to late Cretaeceous. Because of extensive erosion of the uplifted area, roughly concentric outcrops of the various formations are encountered, with the oldest formation cropping out near the center. Beds of unequal hardness have eroded at different rates so that the present topography consists of a series of concentric hogbacks of hard rocks separated by valleys carved in the softer formations. The general drainage pattern is radial, so that the major streams cut across the

concentric valleys and ridges and thus flow alternately in wide valleys and through sharp water gaps and box canyons. In general, the ridges support a growth of pine and cedar, and the valleys are covered with grass, small shrubs, and occasional juniper.

2.2.2. Site Geology.

2.2.2.1. General. The geological formations encountered at the dam site are of sedimentary origin and are of upper Paleozoic and lower Mesozoic age. They include in ascending order, the Minnelusa formation (Pennsylvanian), Opeche formation (Permian); Minnekahta formation (Permian); and Spearfish formation (Permo-Triassic). Pleistocene and recent stream gravels are also present above the sedimentary formations. Descriptions of stratigraphy, structure, and groundwater at the dam site are presented in the following paragraphs.

2.2.2.2. Stratigraphy.

2.2.2.2.1. Minnelusa formation. This formation constitutes the bedrock beneath the valley at the dam site. It is known from outcropping exposures elsewhere that the Minnelusa consists of approximately 500 feet of sandstone, limestone, and shale. Throughout the greater part of the Black Hills the formation is essentially a fine-grained porous sandstone capable of imbibing much surface water and constituting one of the major artesian zones in the plains area east of the Black Hills.

The formation outcrops approximately one half mile upstream from the axis but lies at a depth varying from five to thirty-five feet below the surface at the dam axis. In the vicinity of Cold Brook Dam and elsewhere in the southern part of the Black Hills, the upper zone

of the Minnelusa consists of brecciated and fractured limestone containing local solution cavities throughout. The limestone, which is approximately 12 to 15 feet thick throughout the major width of the valley, grades laterally into a sandy member toward the east or left side of the valley and attains a maximum thickness of 25 feet near the toe of the west or right abutment. The upper portion of the limestone on this abutment changes somewhat in lithology, becoming more clayey in character and apparently grades into a shaley member farther to the west. The limestone beneath the mid-section of the axis is highly dissolved and brecciated and in several cores it was noted that the dissolved and fractured zones have been partially or completely filled and recemented with materials derived from the overlying formations.

A zone of fine-grained orange sandstone approximately 10 to 20 feet thick lies beneath the limestone horizon and this sandstone is underlain by a zone of dense sandy limestone. The lower limestone zone is similar in lithology to the upper zone and contains many open joints and cavities. Logs of exploratory holes Nos. 3 and 5 indicated the presence of an extensive solution cavity in the lower limestone, but this cavity appears to have been refilled by an impervious limey clay.

2.2.2.2.2. Opeche formation. The Opeche formation consists of purple, red, and buff or yellow shales and siltstones interspersed with thin bands of sandy and clayey vari-colored limestones and sandstones. The formation attains a thickness of approximately 145 feet and forms the valley walls at the dam site. The top of the formation is conspicuously marked by a five foot zone of soft limey purple shale which is

underlain by alternate zones of red sandy shale, limey sandstones, thin limestones, and sandstones. The sandy shale beds vary from one to four feet in thickness and are characterized by vertical joints and horizontal bedding planes filled with red clay partings.

2.2.2.2.3. Minnekahta formation. This formation which forms the steep upper walls of the valley at the dam site, consists of about 48 feet of fine-grained, thin bedded to massive limestone; ranging in color from purple to pink to grey. Its thin bedding is characteristic, but the layers are tightly cemented together and the outcropping ledges present a massive appearance. The Minnekahta limestone forms the cap rock of the valley rim on both sides of Cold Brook Dam. Because of the eastward dip of the formations, the Minnekahta lies above the crest elevation of the dam on the west abutment, but constitutes the upper 48 feet of the east abutment (see Plate No. 8). In both outcrops and cores the formation consists of alternate members of pure dense, thin bedded limestone and layers of softer, more massive, argillaceous limestone. Examination of cores reveals that the pure limestone members have frequently been partly dissolved along bedding and joint planes and thus appear as a series of thin, platy beds with partings of calcite or residual red clay. The argillaceous members, on the other hand, have been less dissolved and yield solid cores. Stylolites and small vugs or cavities are rather common throughout the formation, particularly in the pure members.

2.2.2.2.4. Spearfish formation. The Spearfish formation normally consists of about 350 feet of red silty shale containing conspicuous

beds of white gypsum. The principal gypsum bearing member is approximately 100 feet thick, and lies between 100 and 200 feet above the base of the formation. The ridge just to the east of the spillway is capped by the resistant gypsum beds and the contact between the Spearfish and underlying Minnekahta occurs roughly along the centerline of the spillway.

2.2.2.2.5. Pleistocene gravel. At an earlier stage in its history, the valley of Cold Brook became choked with gravel as a result of alluviation processes during the glacial epoch. Renewed downcutting was initiated in the past-glacial epoch and much of the gravel within the confines of the valley was removed, however, remnants of this Pleistocene gravel are still present as terraces downstream from the dam.

2.2.2.2.6. Alluvium and Talus. Bedrock at the dam site is overlain by 33 feet or less of recent stream gravels, silt, clay, and talus from the valley walls.

2.2.2.3. Structure. The geologic structure in the area surrounding the dam is characterized by several slight changes in the rate and direction of dip, and variations of from 5 to 35 degrees in dip are encountered. Along the axis, the dip averages 5 to 6 degrees nearly due east essentially parallel to the axis. The dip in the site of the spillway varies from 7.5 to 10 degress in a south 70 degrees east direction, which is more consistent with the regional trend. No wide scale faulting is known to occur within the reservoir area, but occasional faults of slight displacement are encountered along the outcrop

of the Minnekahta formation, particularly along the outward facing escarpment of this formation along the valley walls. The wide variation of lithology of cores obtained in various deep holes indicates the presence of a local unconformity at the contact between the Minnelusa and overlying Opeche formations. The existence of this unconformity is substantiated by the presence of the brecciated zone near the top of the Minnelusa formation.

2.3. Groundwater. Prior to construction of the dam a large percentage of the yearly flow of Cold Brook Creek passed through the reservoir area as a subsurface flow. This flow of water was most pronounced in the coarse alluvium existing above the bedrock in the valley bottom. The stream normally maintains a year-around surface flow throughout most of its course. However, prior to dam construction the stream passed underground at a point about three-quarters of a mile upstream of the dam and reissued as a surface flow a short distance downstream from the present dam. The average elevation of the groundwater at the dam site before dewatering and excavation operations began was approximately 3535.0.

3. Embankment.

3.1. Embankment Features. The dam is rolled earthfill having an impervious core, a pervious upstream zone and a random downstream zone. The crest elevation is 3675.0, the width is 20 feet and length is approximately 925 feet. The upstream and downstream slopes are symmetrical. From the crest the slopes are 1V on 2.5H down to

elevation 3635 where the slope changes to a 1V on 3H and continues to the natural ground surface. The upstream slope is protected by a 15-inch layer of riprap placed on a 9-inch layer of spalls. The downstream slope is protected from erosion by a 6-inch layer of spalls. The crest was also protected by 6 inches of spalls, however, the spalls on the crest were removed and replaced with topsoil in 1978. There is no chimney or foundation drain provided for seepage control. The natural foundation was believed to be pervious enough to act as a drain. Therefore, a graded filter was placed along the downstream slope of the cutoff trench to prevent piping of the impervious fill downstream into the foundation. Plates 1, 2, and 3 show details of the embankment.

3.2. <u>Material Properties</u>.

3.2.1. <u>General</u>. The primary borrow area for the embankment materials was located in the valley upstream of the dam. Once construction commenced, a shortage of impervious material was discovered requiring the offsite borrow of 160,000 c.y. of impervious fill and the revision of the impervious fill section to reduce the required quantity. This reduction was matched by a corresponding increase in the random fill quantity. This increased quantity of random fill was obtained from the upper end of the main borrow area and was predominantly silt.

3.2.2. <u>Borrow Area Testing</u>. Tests conducted on the borrow material included Atterberg Limits, mechanical analysis, standard compaction, direct shear, consolidation and permeability. Mechanical analysis

tests were conducted on the entire field sample, while the specimens for the other tests were composed of only the minus No. 4 sieve material. Plate 11 is a table presenting the results of the borrow area testing. It is not known for which zone of the embankment these tested materials were intended. However, the mechanical analysis tests indicate that samples from the first three test pits would have been suitable material for impervious fill.

The range of test values for these test pits are presented below:

Liquid Limit	18 to 39
Plastic Index	3 to 17
Percent Fines	25 to 77 with one sample at 16
Standard Compaction Test	
Maximum Density	110.0 pcf to 125.2 pcf
Optimum Moisture	9.6% to 15.2%
Direct Shear Test	
(Constant Strain at 0.02 inches per minute)	c = 0.10 TSF, Tan Ø = 0.47 to c = 0.23 TSF, Tan Ø = 0.61

The mechanical analysis for the last test indicates that the material could be used as random fill because it appeared to have too much fine material to be used as pervious fill.

3.2.3. Foundation Testing. The testing program for the foundation material was similar to that which was used for the borrow materials. The only addition was that some consolidation and direct shear tests were run on undisturbed specimens. Plates 12 and 13 present the results of the foundation testing. The range of these test values are presented below:

Liquid Limit	19 to 45
Plastic Index	1 to 17
Percent Fines	2 to 87
Standard Compaction Test	
Maximum Density	110.0 to 129.8
Optimum Moisture	9.0 to 13.4
Direct Shear Tests	
(Constant Strain at 0.02 inches per minute)	
Remolded Specimens	c = 0.00 TSF, Tan Ø = 0.51 to
	c = 0.05 TSF, Tan Ø = 0.70
Undisturbed Specimens	c = 0.10 TSF, Tan Ø = 0.43 to
	c = 0.0 TSF, Tan Ø = 0.62

3.3. Embankment Stability Analysis.

3.3.1. Design Stability Analysis. For the design of the embankment, only the downstream steady seepage case was analyzed since it was believed to be the most critical case. For this case it was assumed that 75 percent of the piezometric head loss occurred across the cutoff

and the impervious core, with the remainder dissipated in the pervious upstream zone and foundation. The assumed soil properties were (1) embankment material, shear strength c = 0.10 TSF and Tan Ø = 0.60 with a unit weight of 120 PCF; (2) foundation material, shear strength c = 0.0 TSF and Tan Ø 0.50 with a unit weight of 125 PCF.

Two stability analysis methods were used for the embankment design. One method provided an approximate solution using slope charts. This procedure was proposed by W. Fellenius in "Calculations of the Stability of Earth Dams," 2nd Congress, on Large Dams, Washington, 1936, Volume IV. The preliminary slopes provided by this approximate method were then verified by the graphic method also proposed by Fellenius. The factors of safety were 1.72 for the right abutment section, 2.08 for the left abutment section, and 1.83 for the valley section.

3.3.2. Stability Reevaluation. OCE and MRD in the 1st and 2nd Indorsements to the Periodic Inspection Report No. 1, May 1970, requested that the embankment stability of Cold Brook Dam be reevaluated using present day criteria. This reevaluation was completed and presented as Appendix E of the Periodic Inspection Report No. 2, September 1975.

The soil strengths and properties assumed in the reevaluation are presented in Table 1 below.

TABLE 1

MATERIAL	UNIT WEIGHT KCF		TAN Ø			COHESION, KSF		
	Moist	Sat'd	R	S	(R+S)/2	R	S	(R+S)/2
Pervious & Random Fill	0.120	0.125		0.60			0	
Impervious Fill	0.120	0.125	.25	0.50	0.38	.5	0	.25
Foundation Alluvium & Talus	0.120	0.125	.25	0.50	0.38	.5	0	.25

These values were not based on actual test results but were assumed properties based primarily on the material type and the original design strengths. The cases analyzed included sudden drawdown, partial pool with and without earthquake forces and steady seepage with and without earthquake forces.

The results of the reevaluation are presented in Table 2 below and Plates 14, 15, and 16 summarize each case.

TABLE 2

Case		Arc Base Elevation	Factors of Safety Actual	Recommended
Sudden Drawdown with Partial Pool Assumptions	Spillway pool (3646.5)	3530	1.32	1.20
	Surcharge pool (3667.2)	3530	1.43	1.00
Partial Pool Pool At El. 3585	Without Earthquake	3530	1.25	1.50
	With Earthquake	3530	1.03	1.00
Steady Seepage	Spillway Pool Without Earthquake	3510	1.45	1.50
	Spillway Pool With Earthquake	3510	1.21	1.0
	Surcharge Pool Without Earthquake	3510	1.33	1.40

The reevaluation showed that the dam was stable for all conditions analyzed; however, the factors of safety for the sudden drawdown case and partial pool case were below the currently recommended design values. Based on the reevaluation it was deemed prudent to obtain and test undisturbed samples of the various materials in the embankment and foundation to verify the strengths used.

The samples were obtained during the installation of piezometers in 1978. Tests on these samples showed that in-place strengths exceeded the previously used assumed strengths. Subsequent analyses showed that the factors of safety meet current criteria for all cases.

4. Foundation Treatment.

4.1. Cut-off Trench. A cut-off trench to bedrock was provided to intercept possible seepage channels or gravel pockets. The base width of the trench was 20 feet and was keyed into the foundation rock a minimum of 5 feet. The side slopes in rock were 4V on 1H and in overburden were 1V on 1½H. The trench was backfilled with impervious material. Plate No. 17 shows a plan and typical section of the trench, and Photos 3, 4, and 5 show views of trench.

4.2. Abutment Overexcavation. The foundation exploration revealed that some low density talus and alluvial material near the abutments could consolidate excessively. Therefore, since the cutoff trench was going to require extensive excavation at the abutments, it was decided to overexcavate and recompact any low density materials. The extent of the overexcavation is not known because of the lack of construction records.

4.3. Foundation Grouting. The grout curtain consists basically of a single line of 93 holes spaced on 10-foot centers with a 40-foot average depth. In addition, some areas in the upper zone of the foundation were deemed critical. Therefore, in these areas a second line of grout holes was established. This line was located 5 feet upstream of the primary line with the average hole depth of 15 feet. Fifteen holes were drilled and grouted, with only three holes accepting grout. Plates 17 and 18 show a plan and profile of the grout curtain. Plate No. 18 also shows a bar graph of the grout takes for all of the holes. Additional information on the grouting program is contained in the Cold Brook Foundation Report.

4.4. Grout Curtain Extension. Review of the construction report raised the question that the grout curtain may not have extended far enough into the left abutment. It indicated that during high pool stages flow paths could develop around the grout curtain and result in serious erosion of the embankment. Subsequent studies revealed that the grout curtain should be extended. In September of 1978, a contract was let to W. G. Jaques Company, Des Moines, Iowa, to extend the grout curtain 110 feet into the left abutment. Grouting operations commenced in October 1978, were completed in February 1979. Approximately 16,000 cu. ft. of grout were placed. The program consisted of a single line of both vertical and angled holes (angled 30° and 45° from the vertical), located on the dam centerline, with additional holes located 2.5 and 5 feet upstream of the centerline, adjacent to the embankment abutment contact. Most of the grout holes extend through the Minnekahta

formation and terminated 5 feet into the Opeche formation. Most of the grout take was experienced in the Minnekahta formation with the Opeche formation taking very little. Additional information on the grout curtain extension is contained in Appendix A of the Cold Brook Foundation Report.

4.5. Blanketing. The downstream extent of the borrow area was limited in order to leave a blanket of natural material upstream of the dam. The size of the blanket is not known, but was believed to extend 500 feet upstream of the embankment.

4.6. Effectiveness. This project has not experienced a pool level higher than el. 3585, therefore, the effectiveness of the foundation treatment in the abutments above elevation 3585 has not been tested. The valley, however, appears to be impervious. Once the grout curtain was complete and the cutoff trench backfilled, water began to pond although there was no surface flow in Cold Brook Creek. Also at this time, shallow wells downstream of the dam began to dry up. More recently piezometers were installed to monitor the effectiveness of the foundation treatment. Plate No. 22 shows the location and record of these piezometers. Although the record of readings is short they indicate that the foundation treatment is effective.

5. Instrumentation.

5.1 General. The instrumentation at Cold Brook Dam is summarized in Table 3.

TABLE 3

Type of Instrumentation	Location	Number	Year Installed
Movement Pins	Dam Crest	5	1972
Elevation Points	Outlet Conduit Invert	93	1976
Elevation Points	Intake Structure	4	1976
Elevation Points	Stilling Basin	10	1977
Piezometers	2 on Dam Crest 6 at Dam Toe	8	1978

There was no instrumentation installed at the dam prior to 1972; therefore, the record of instrumentation data is relatively short compared to the time the dam has been in operation.

5.2. Dam Crest Movement Pins. Plate 19 shows the locations and a typical installation for these movement pins. This plate also presents the movement readings taken to date. The maximum settlement observed is 0.12 feet and occurred at MP 5 which is near the right abutment. The maximum movement in the upstream-downstream direction is 0.08 feet upstream and occurs at MP 4. These movements are not considered significant.

5.3. Outlet Conduit Elevation Points. Plate 20 shows the location of the elevation points in the conduit. This plate also presents the elevation readings of the points. The initial readings were taken in August of 1976 and a subsequent reading was taken in August of 1977. These two readings indicate an apparent uniform rebound of approximately 0.015 foot. This magnitude of movement is not considered significant.

5.4. Intake Structure Elevation Points. Plate 21 shows the location of the points on top of the intake structure. This plate also

presents the elevation readings of these points. The initial readings were taken in August of 1976 and subsequent readings were taken in August of 1977 and indicate that no movement has occurred.

5.5. Stilling Basin Elevation Points. There are a total of 10 Elevation Points on the stilling basin wing walls (5 on each wall). The points were initially read in August 1977 and subsequent readings have not been taken.

5.6. Piezometers. Plate 22 shows the location of the eight piezometers at this project. Also shown on this plate is a typical installation detail and a plot of the piezometric readings to date. Three of the piezometers (deep) monitor water levels in the sandstone bedrock. The other five piezometer (shallow) monitor water levels in the foundation alluvium. The readings to date show that there are no significant pressures under the embankment. This indicates that the foundation cutoff is effective for pool levels up to elevation 3585.

6. Embankment Construction.

6.1. General. The primary contractor for this project was Northwestern Engineering Company of Rapid City, South Dakota. They employed two subcontractors, Boyles Brothers Drilling Company, responsible for the foundation grouting, and Emme Construction Company, who did the foundation excavation. The full extent of Emme Construction Company's responsibility is not known.

There is little written information available on the construction of this project. The following sections attempt to summarize the available written data; however, the photos in Appendix A provide a

pictorial record of the construction operations.

6.2. <u>Changes From Project Plans</u>. During the course of construction, departures from the Definite Project Plans became necessary. Some of the major changes that are on record are described in the following paragraphs.

One change was ordered on 14 July 1950. The contractor was directed to eliminate the water level recorder well and piping on 6 November 1950. He was directed to install a water level recorder according to drawings that were furnished him at the time by the Corps of Engineers.

Another change resulted during excavation for the downstream concrete monolith of the conduit. At that time, it was found necessary to excavate below the planned grade in order to obtain a satisfactory foundation. Therefore, on 28 December 1950, the contractor was directed to dig test pits to explore the foundation conditions in the area of the stilling basin. As a result of the foundation exploration, the Definite Project Design of the stilling basin was modified in April of 1951, to allow the basin floor slabs to rest on firm shale with a minimum of fill concrete.

Several changes in the grouting program occurred during construction. One of the changes occurred on 1 May 1951. At this time, the Government furnished fly ash and an intrusion aid for grouting in areas upstream of the cutoff trench. This was done as an additional precaution against reservoir leakage. Additional information about the grouting program is contained in the Cold Brook Foundation Report.

One change in spillway construction was made on 31 March 1953. At this time, the contractor was directed to install a compacted earth levee with rock riprap protection between the end of the left wing wall of the concrete spillway structure and the natural ground contour at elevation 3655.5 for the purpose of preventing the possibility of the wing wall being flanked by a flood of "reservoir design" magnitude.

The largest change from the Project Plans occurred in the embankment zoning. The change resulted from several interrelated occurrences which began with the decision to provide a natural blanket of material upstream of the dam. This natural blanket (which extended approximately 500 feet upstream of the dam) was material that was scheduled to be used as embankment fill. The loss of this material combined with the relatively small amounts of impervious material in the borrow area caused a 315,000 cubic yard shortage of impervious fill. To make up for this shortage, the width of the impervious section above elevation 3560 was reduced to one-half the design width, and an additional borrow area for approximately 160,000 cubic yards of impervious fill was located.

The revision of the dam section increased the required quantity for pervious and random materials, which resulted in a shortage of random material. This shortage was partially met by using silty material from the upstream limit of borrow area, and partially by the use of waste rock. The revised dam section is shown on Plate 2.

6.3. Specification Requirements.

6.3.1. Compaction Equipment. Two types of compaction equipment were specified to be used on this project. One type was a crawler type tractor, the other a sheepsfoot (tamping) roller.

The crawler type tractor was to be used to compact the gravel filter layer on the downstream slope of the cutoff trench. The specifications called for a tractor weighing not less than 20,000 pounds and exerting a unit pressure of not less than 6 pounds per square inch (p.s.i.).

The sheepsfoot roller was to be used to compact all of the other materials. The specifications for the roller called for a cylindrical drum not less than 48 inches long, with metal tamping feet not less than 7 inches long, and spaced not less than 6 nor more than 10 inches apart (measured diagonally). The roller was to exert a foot pressure of at least 400 p.s.i. when fully loaded, and not more than 250 p.s.i. when empty. It was further specified that the roller should be pulled by a crawler tractor. Photo 7 shows the sheepsfoot roller on the fill.

6.3.2. Material, Placement and Compaction.

6.3.2.1. Impervious Fill. The specifications required impervious fill to consist of clays, silty clays, or clayey silts. Also, silts and clays containing some sand were allowed if the material was sufficiently impermeable. For placement, the material was to be spread in horizontal layers not greater than 9 inches thick. After spreading the water content was to be adjusted to as near to optimum as practical, and then the layer was to be compacted by eight passes of the sheepsfoot roller.

It is believed that the intended density of the material was to be between 90 and 95 percent of standard compaction maximum density.

6.3.2.2. Pervious and Random Fill. The specifications called for the pervious material to be free draining sand or sand and gravel that was free from objectionable coatings and contained not more than 10 percent by weight silt or clay. The random material was to consist of all other types of material which was suitable for use in the embankment, including soft weathered rock which could be readily compacted. The specifications for the placement of these materials were identical to the impervious fill. However, the compaction for these materials called for only six passes of the sheepsfoot roller.

6.3.2.3. Gravel Filter Material. The gravel filter material, which was used on the downstream slope of the cutoff trench, was to consist of tough, durable gravel or crushed rock having the following gradation:

Sieve Size	Percent Passing by Weight
4"	100
2"	93-100
1"	87-100
#4	60-100
#10	42-98
#40	18-72
#100	2-10
#200	0-6

The specifications for placing this material were also similar to those for the impervious fill. Compaction, however, was accomplished by not less than four passes of a crawler type tractor.

6.4. Construction Operations.

6.4.1. Borrow Areas. The material for the fill was obtained from five borrow areas located near the embankment. Table 3, below, summarizes the borrow areas and their locations:

TABLE 3

Location	Borrow Area
A	Upstream of Dam
B	Left Abutment of Dam
C	700 Feet West of Spillway
D	1,000 Feet North of Spillway
X	Unknown

During construction operations, the origin of the borrow material did not dictate in which zone the material was to be used. However, most of the pervious material came from the stream bank in Borrow Area A, and most of the riprap came from Borrow Area B.

6.4.2. Fill Placement. Photo 7 shows various operations on the fill. During construction every attempt was made to place the most impervious material in the impervious s ion. If the material did not meet the impervious fill requirements, t was used in the random zone. In the random zone, the more pervious materials were placed toward the downstream limit of the dam, while the more impervious random materials were placed adjacent to the impervious fill. In the pervious zone of the dam, the same method of fill placement was adopted, where the most pervious was placed on the outer slope and the least pervious near the impervious zone. The intent of these procedures was to make the central portion of the embankment impervious, and the shells of the dam pervious.

6.4.3. Riprap and Spall Placement. Photo 9 shows the method of riprap placement. It appears that the spalls were first placed on the slope and then the riprap was dumped into place from trucks. The final adjustments of the stones was then made by hand.

6.4.4. Closure. The closure section for this embankment was located adjacent to the left abutment. The required width of the section was 20 feet. Once the embankment reached elevation 3610, closure could be made. Photo 8 shows a view of the closure section.

7. Construction Experiences. The unanticipated shortage of material in the borrow area probably constitutes the most significant lesson to be learned from the construction of this embankment. The exploration program in the borrow area was not of sufficient scope to accurately define the quantity of each material type. Although some of the material shortage experienced during construction was caused by limiting the extent of the borrow area, additional shortages were caused by overestimates of material available for use. In future dam construction, when the borrow areas are variable, the designers should be certain that their exploration program is of sufficient extent to adequately define the quantities of materials available.

8. Operation History.

8.1. Pool Levels. Since completion in 1953, the project has not experienced a significant flood event. The highest pool level to date has reached elevation 3585 which is 61.5 feet below the emergency spillway crest elevation.

8. Operation History.

8.1. Pool Levels. Since completion in 1953, the project has not experienced a significant flood event. The highest pool level to date has reached elevation 3585 which is 61.5 feet below the emergency spillway crest elevation.

8.2. Embankment Performance. The embankment has performed satisfactorily. There have been no slides, seeps, cracks or sinkholes observed at the dam.

8.3. Instrumentation Response. The movement pins located on the crest seem to indicate continuing settlement of the dam. However, since monument CM-1 is used as a datum and since it is located in an old borrow area, the assumed settlement of the dam may actually be rebound of the monument CM-1. In either case the magnitude of the settlement (or rebound) is small and is considered a normal response. The other instrumentation shows no significant trends. Based on the instrumentation response the embankment appears to be functioning satisfactorily.

APPENDIX A

PHOTOGRAPHS

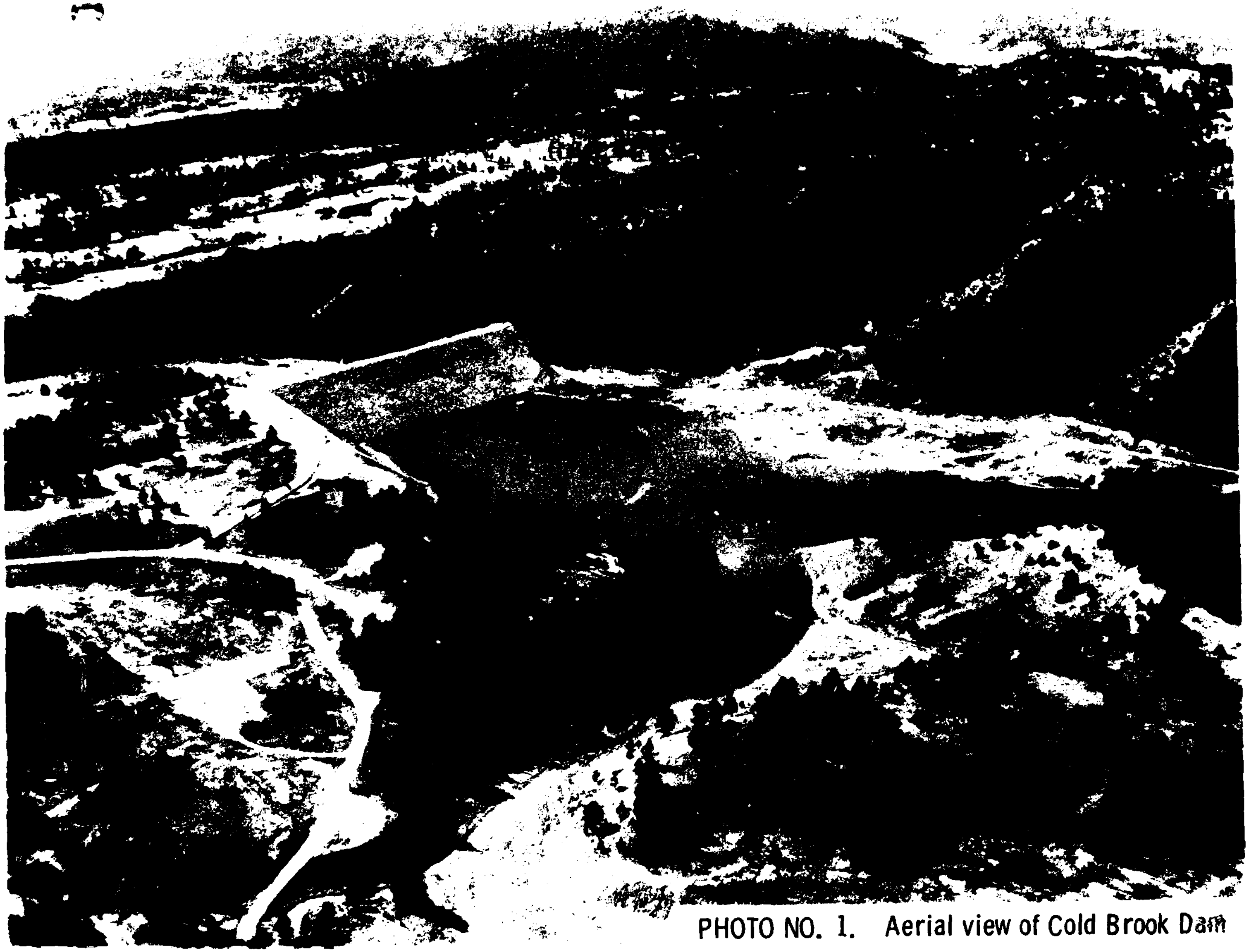


PHOTO NO. 1. Aerial view of Cold Brook Dam

PHOTO NO. 2. Overall view of the early stages of construction

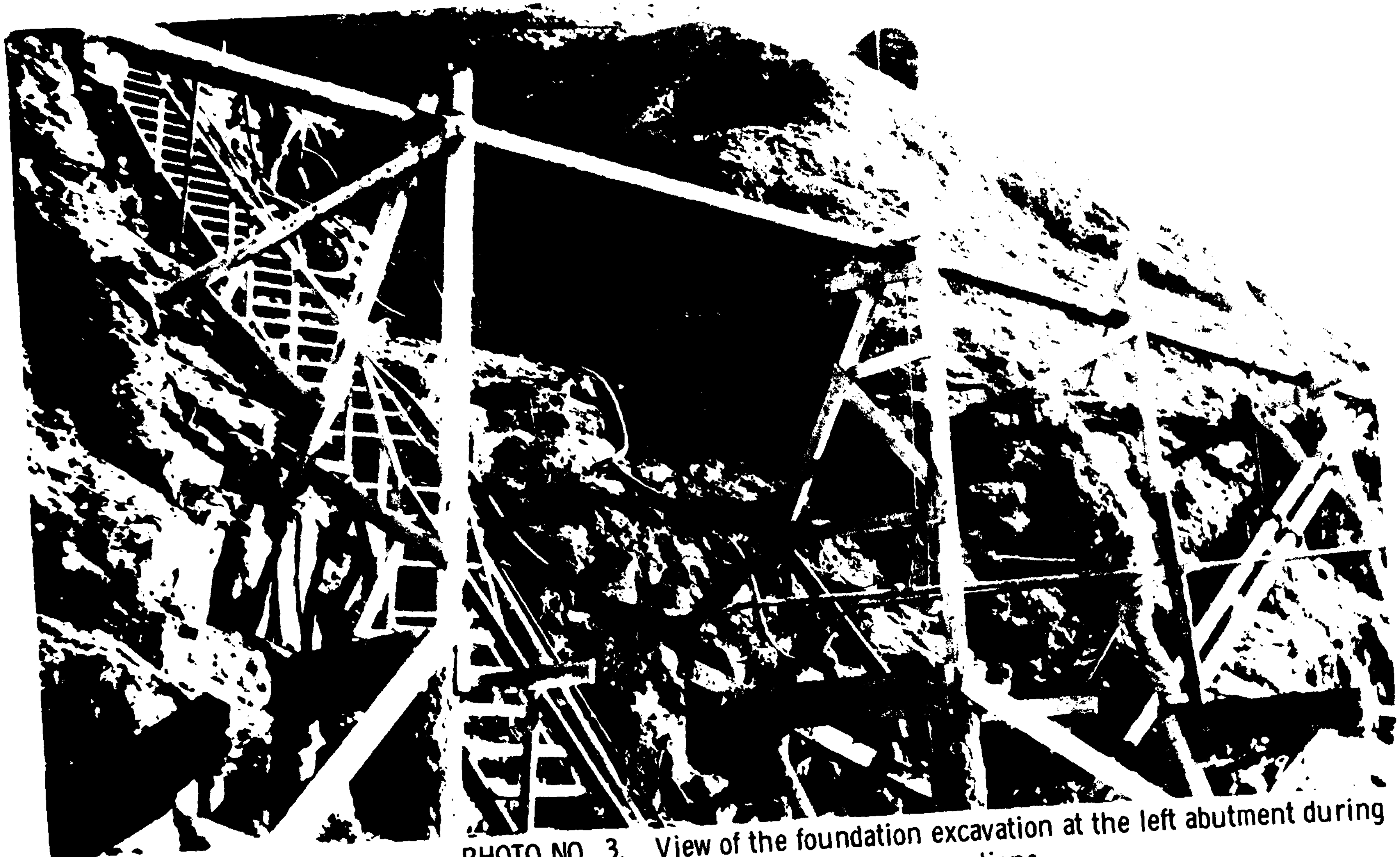
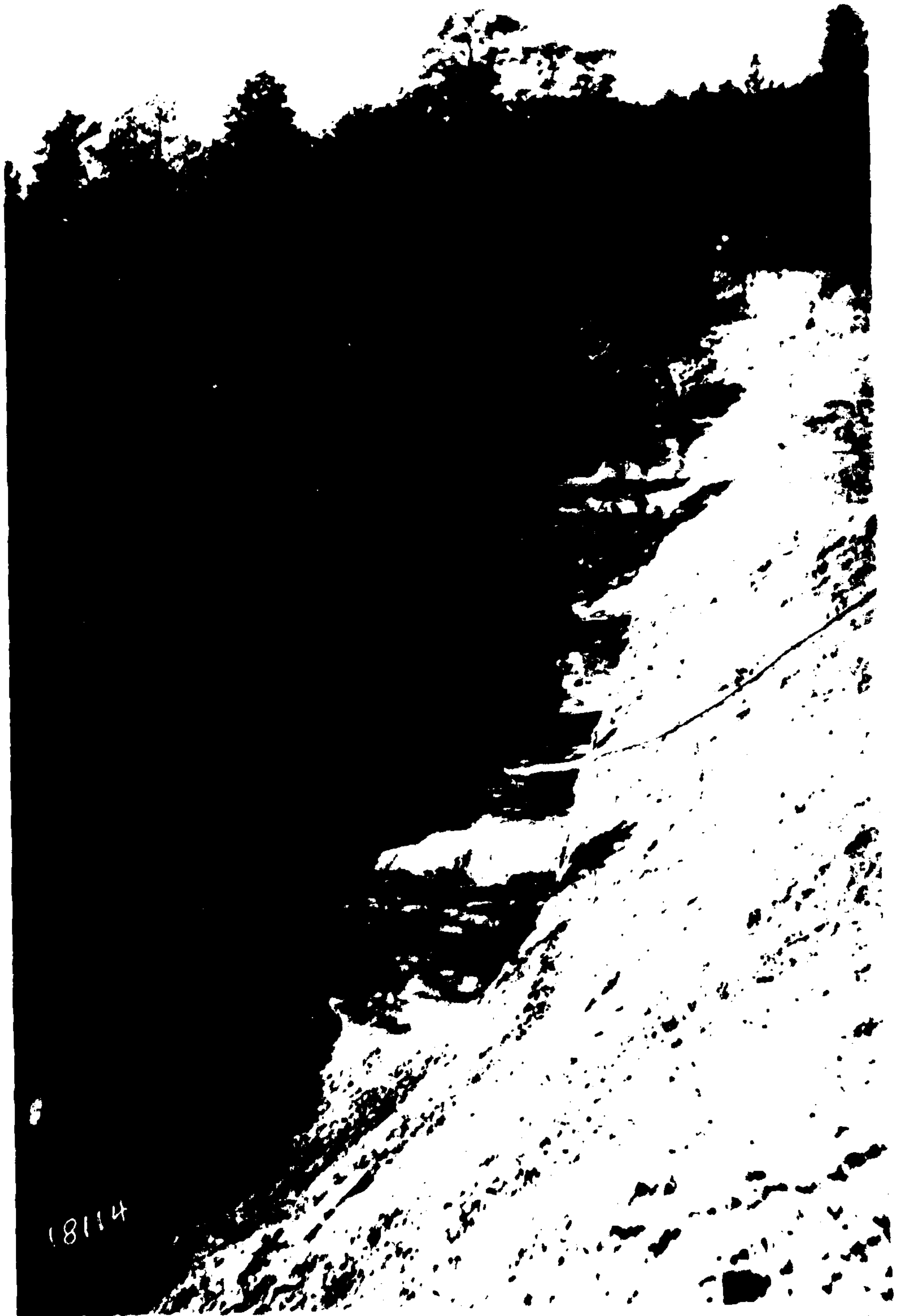


PHOTO NO. 3. View of the foundation excavation at the left abutment during drilling and grouting operations.



HOTO NO. 4. View of the foundation excavation at the right abutment

PHOTO NO. 5. View of the valley section of the cut-off trench before rock excavation.

PHOTO NO. 6. General view of the damsite showing the conduit partially in place and the initial stages of the embankment construction. Note the closure section located at the right of the photo.

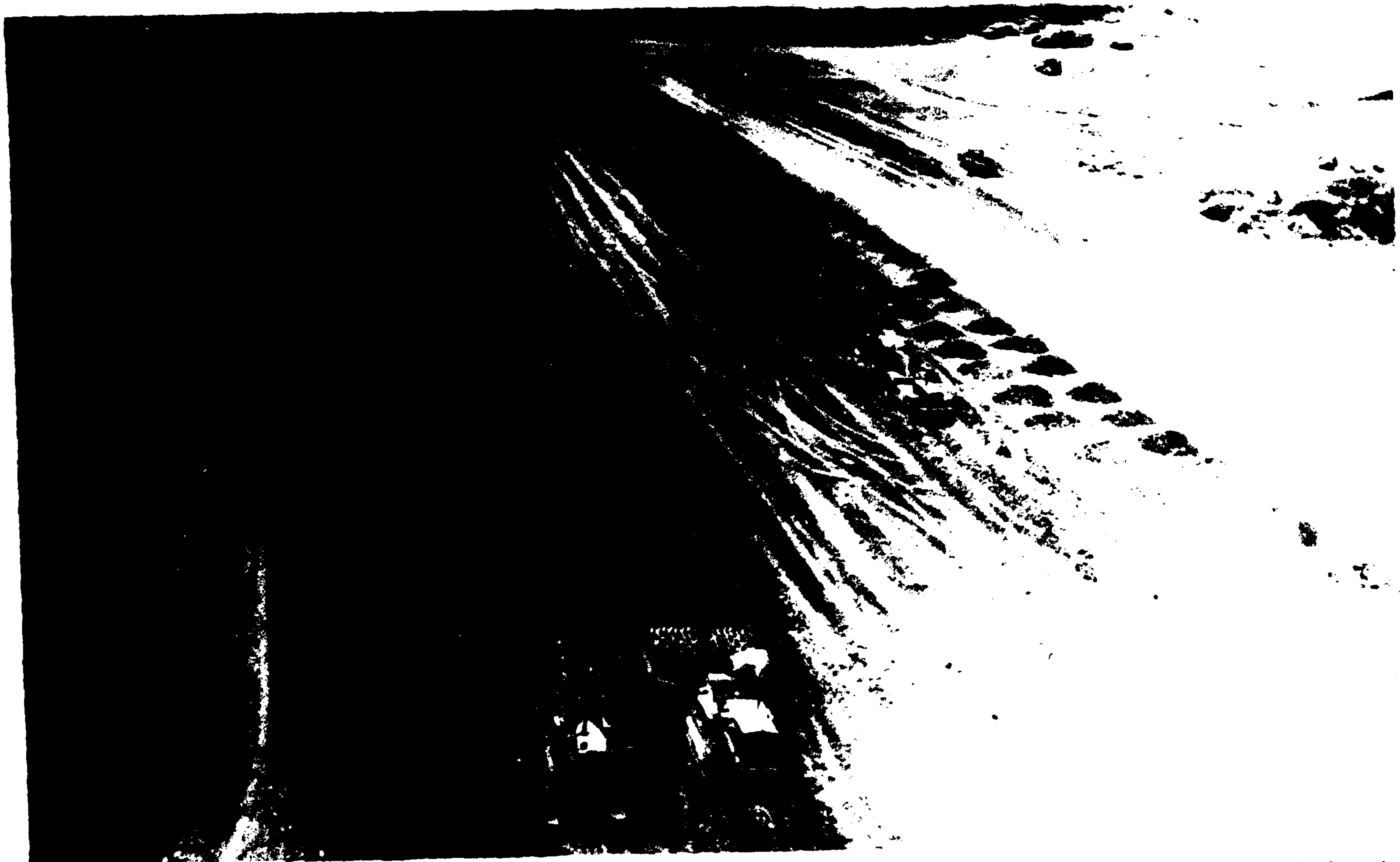


PHOTO NO. 7. View of operations on the fill looking toward the right abutment. Pervious fill placed by dump trucks at far right of photo. Impervious fill placed by scraper and rolled by sheepsfoot roller in center of photo. Random fill at left of photo.

PHOTO NO. 8. View of the closure operations. Photo taken looking downstream.

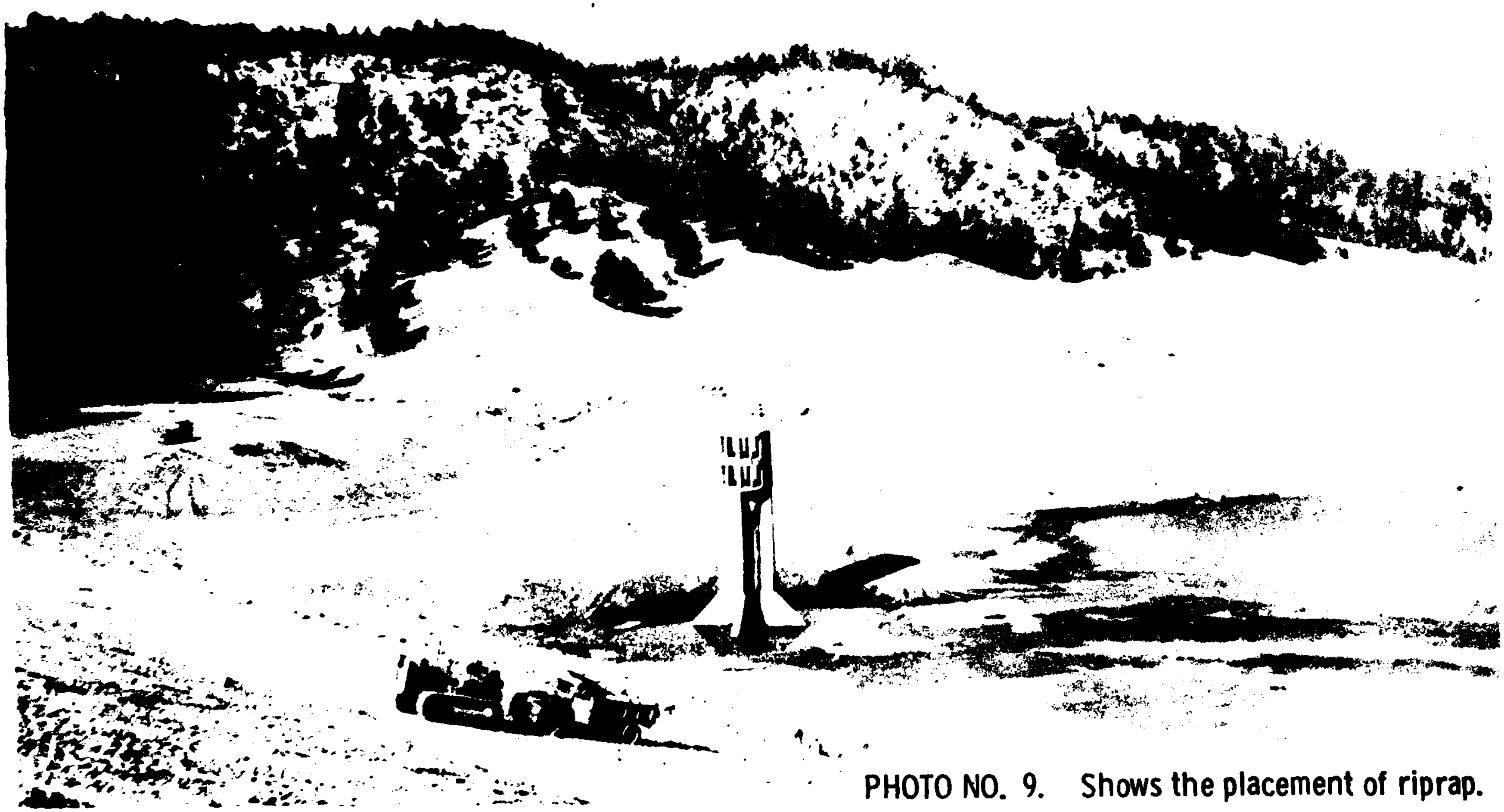


PHOTO NO. 9. Shows the placement of riprap.

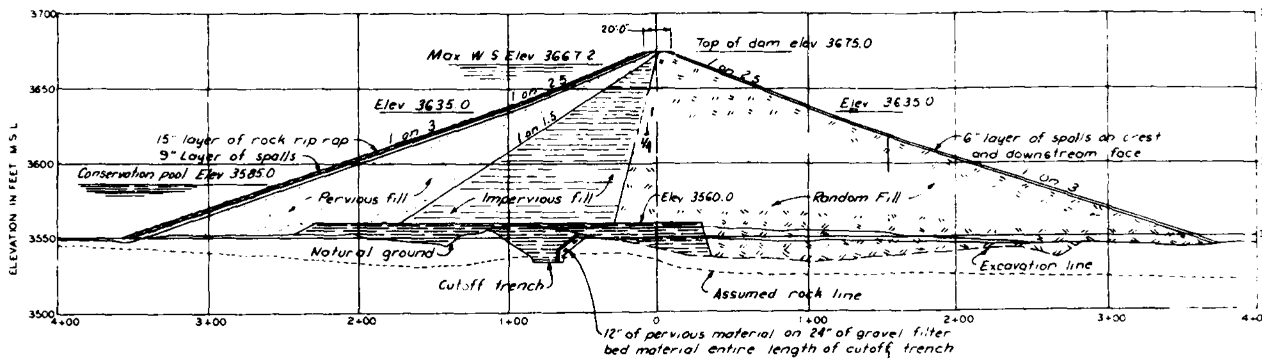
PHOTO NO. 10. View of the completed upstream slope with pool at El. 3562.3.

PHOTO NO. 11. View of completed stilling basin.

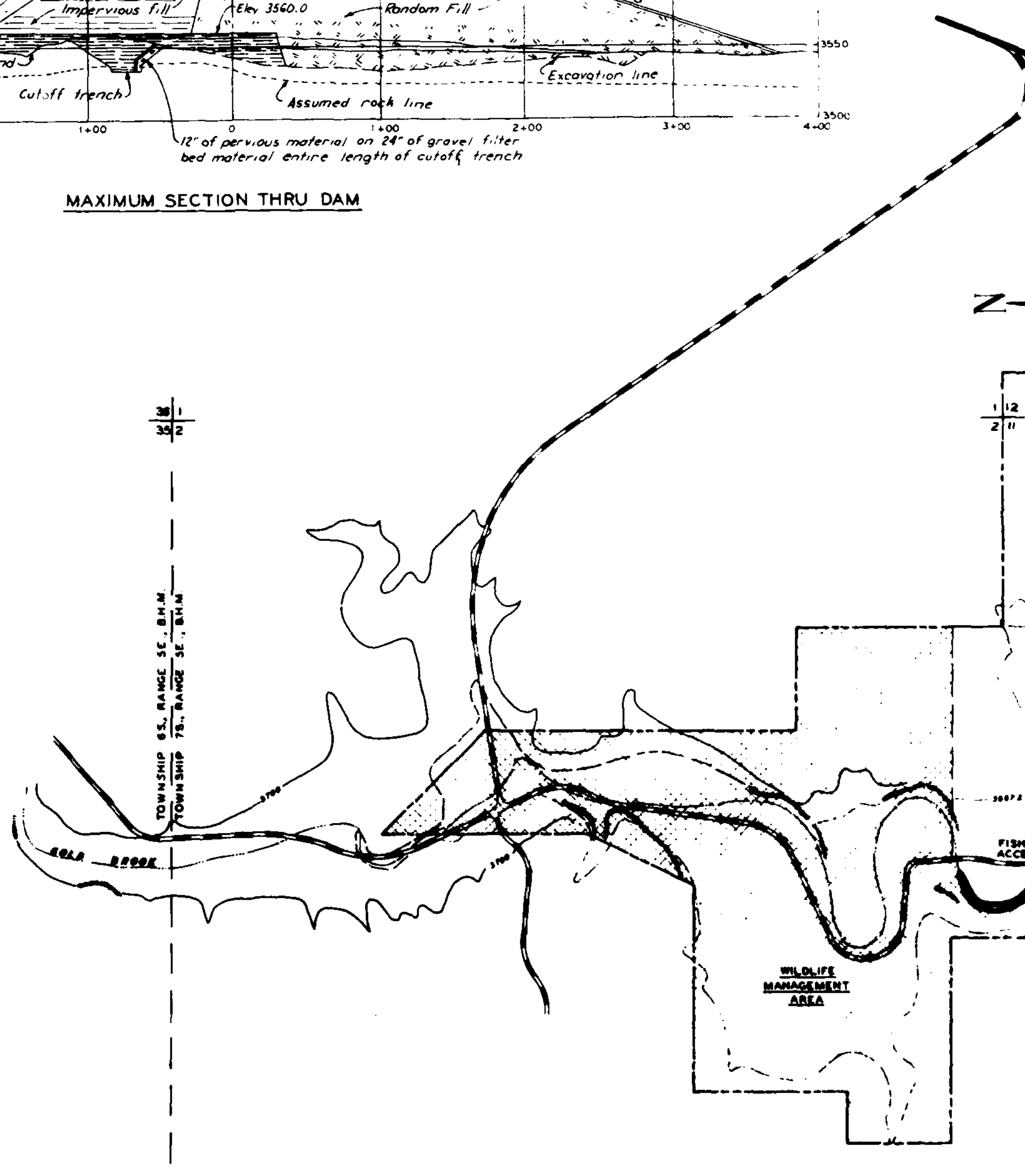
APPENDIX B

PLATES

CORPS OF ENGINEERS

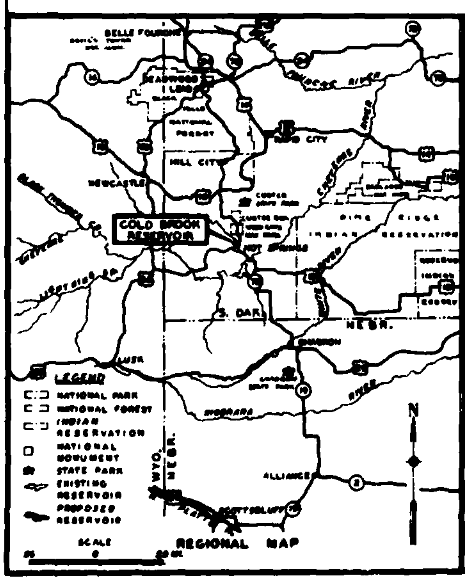


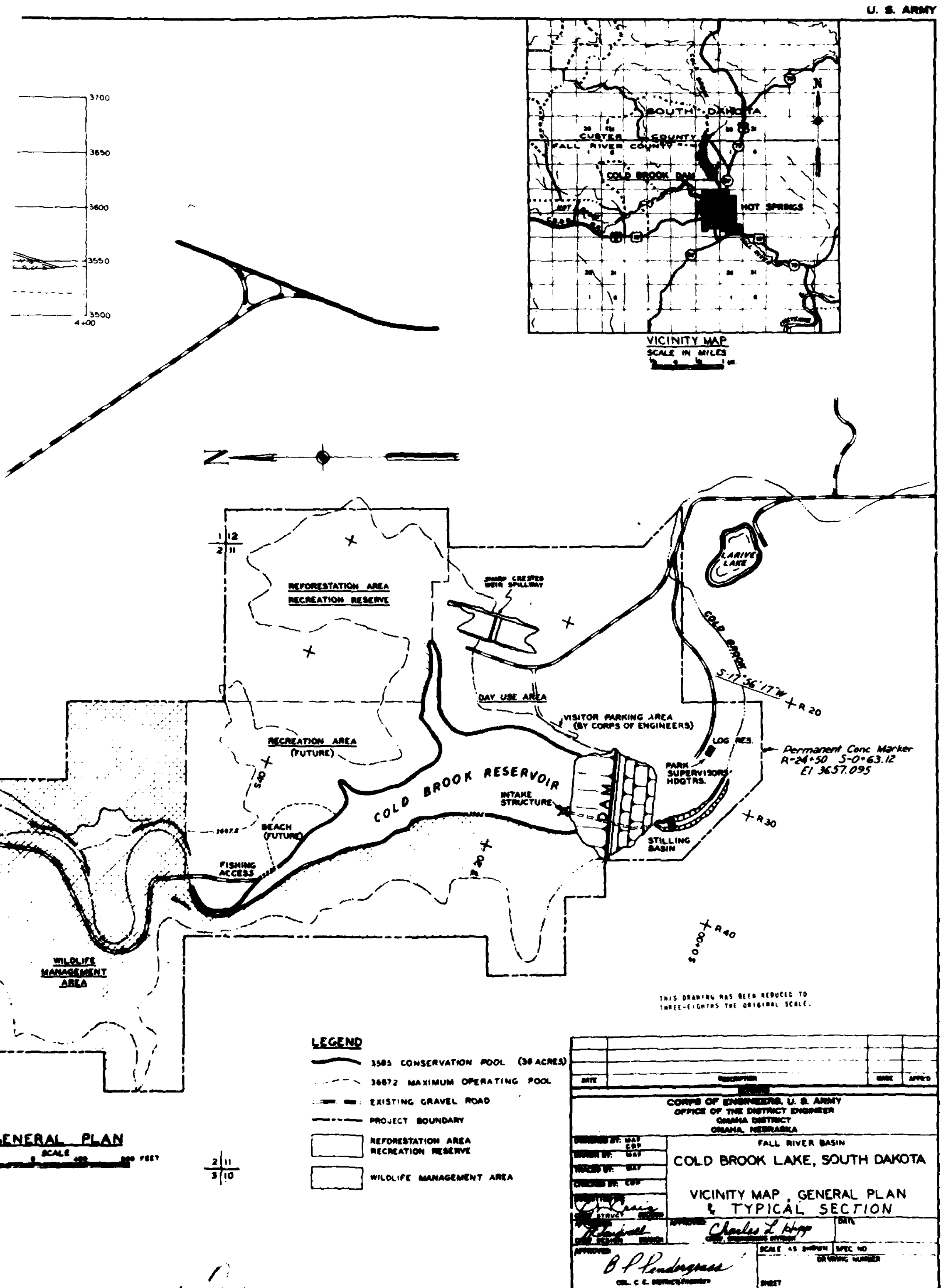
MAXIMUM SECTION THRU DAM



GENERAL PLAN

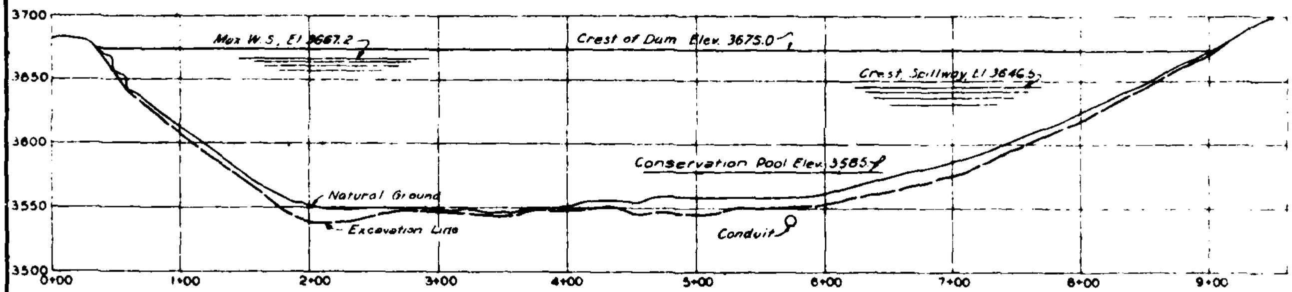
SCALE



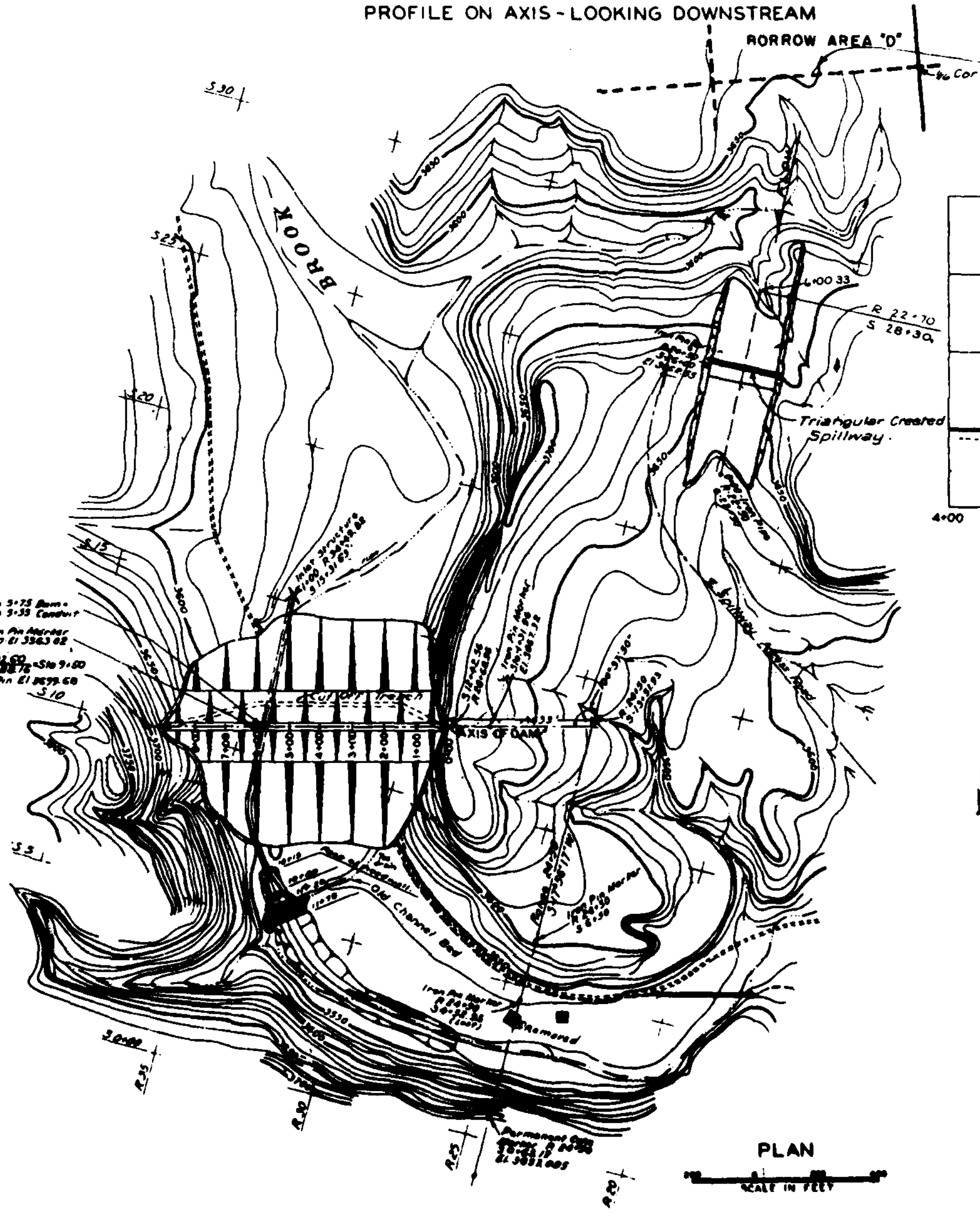


U. S. ARMY
3700
3650
3600
3550
3500
4+00
SOUTH DAKOTA
CUSTER COUNTY
FALL RIVER COUNTY
COLD BROOK DAM
HOT SPRINGS
VICINITY MAP
SCALE IN MILES
LARIVE LAKE
COLD BROOK
S-17°56'17"W
R 20
SHARP CRESTED WEIR SPILLWAY
REFORESTATION AREA
RECREATION RESERVE
DAY USE AREA
VISITOR PARKING AREA
(BY CORPS OF ENGINEERS)
LOG RES.
Permanent Conc Marker
R-24+50 S-0+63.12
El 3657.095
RECREATION AREA
(FUTURE)
COLD BROOK RESERVOIR
INTAKE STRUCTURE
DAM
PARK SUPERVISORS HDQTRS.
R 30
STILLING BASIN
BEACH
(FUTURE)
FISHING ACCESS
R 40
0+00 S
WILDLIFE MANAGEMENT AREA
THIS DRAWING HAS BEEN REDUCED TO THREE-EIGHTHS THE ORIGINAL SCALE.
LEGEND
3585 CONSERVATION POOL (36 ACRES)
3667.2 MAXIMUM OPERATING POOL
EXISTING GRAVEL ROAD
PROJECT BOUNDARY
REFORESTATION AREA
RECREATION RESERVE
WILDLIFE MANAGEMENT AREA
GENERAL PLAN
SCALE
CORPS OF ENGINEERS, U. S. ARMY
OFFICE OF THE DISTRICT ENGINEER
OMAHA DISTRICT
OMAHA, NEBRASKA
FALL RIVER BASIN
COLD BROOK LAKE, SOUTH DAKOTA
VICINITY MAP, GENERAL PLAN & TYPICAL SECTION
Charles L. Hopp
B P Pendergrass
COL. C. E. DISTRICT ENGINEER
SCALE AS SHOWN
DRAWING NUMBER
SHEET

CORPS OF ENGINEERS

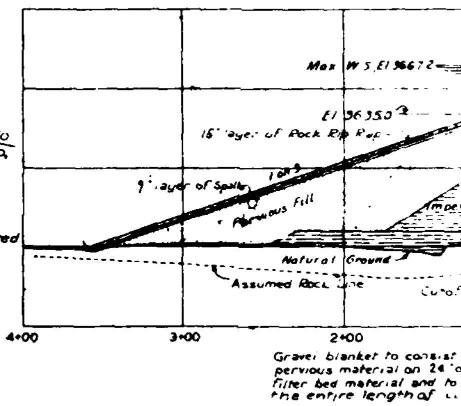


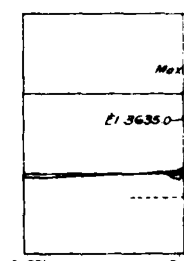
PROFILE ON AXIS - LOOKING DOWNSTREAM

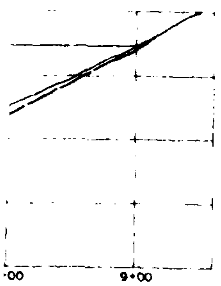


PLAN

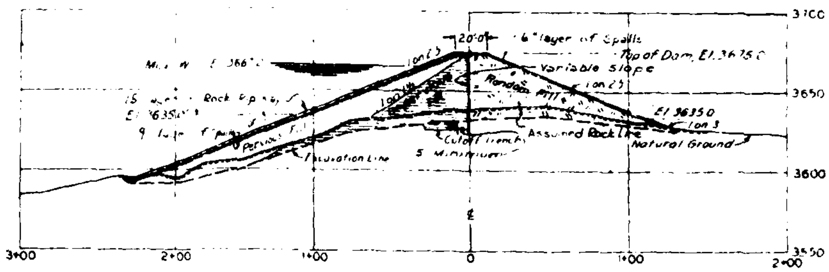
SCALE IN FEET



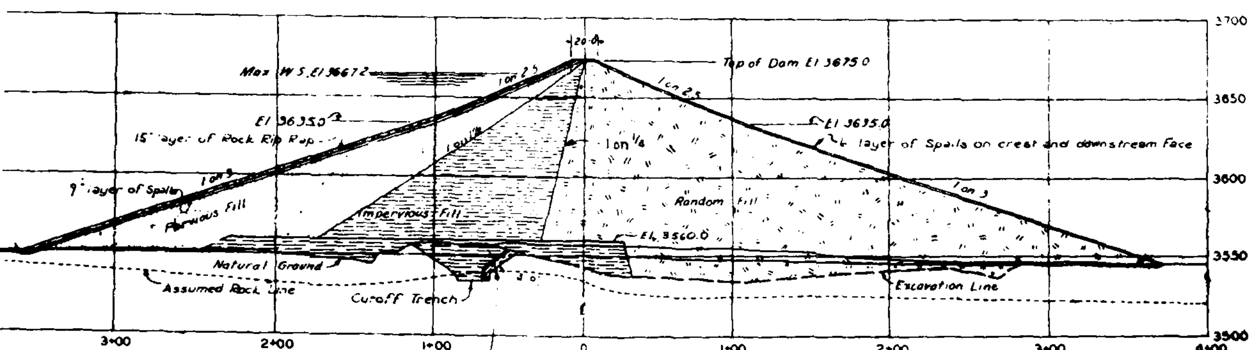




Note:
Borrow area 'D' is located in the E½ of NE¼ of NE¼, Sec. ?, T 7S, R5E, BHM.



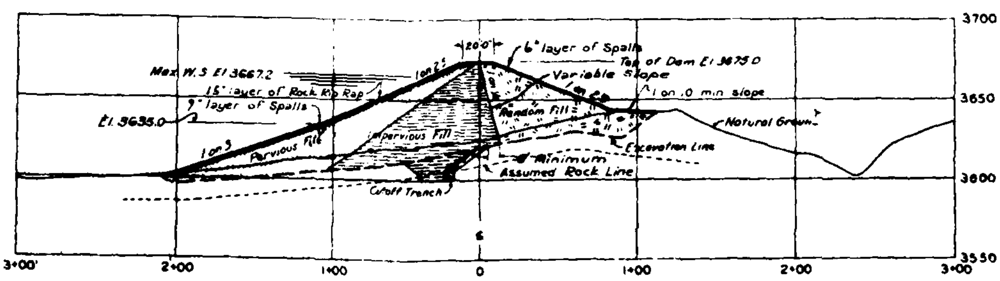
SECTION-LEFT ABUTMENT
STA 0+65



Gravel blanket to consist of 12" of pervious material on 24" of gravel filter bed material and to extend the entire length of cutoff trench

MAXIMUM SECTION
STA 5+50

Note: Excavation line shown to reach pervious strata & to remove unsuitable material



SECTION-RIGHT ABUTMENT
STA. 8+00

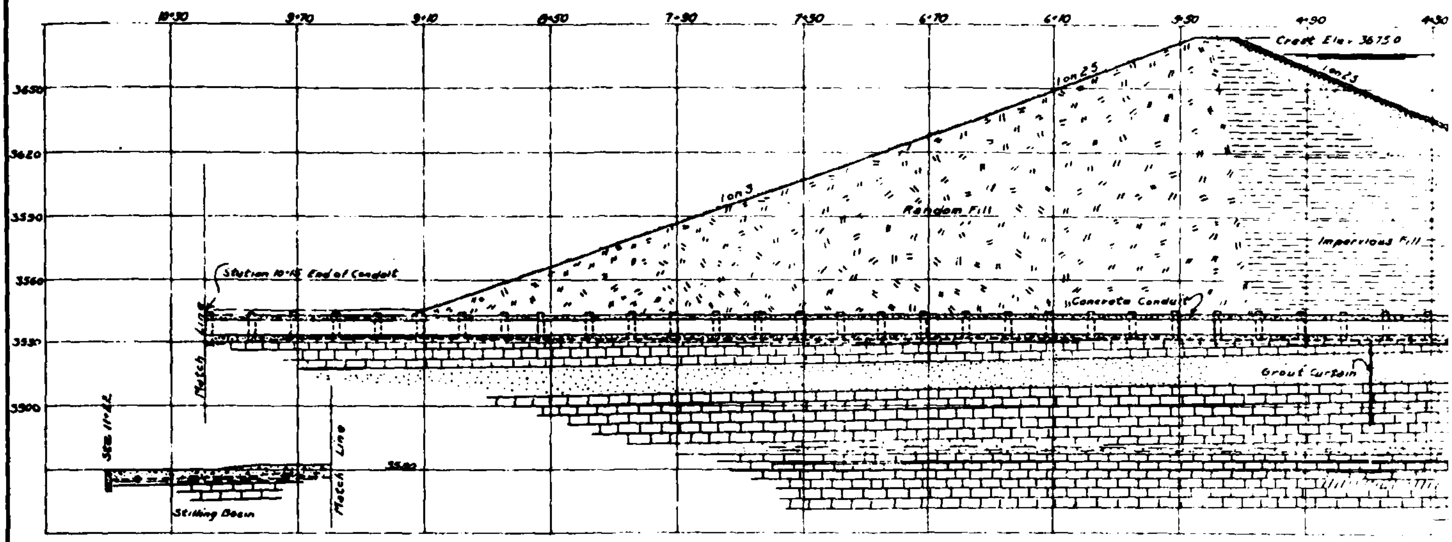
No.	Description	Date	Approved
6	Borrow Area 'D' & Note added	4-16-52	[illegible]
5	Impervious Fill section revised	6-7-51	[illegible]
4	Thickness of Riprap and spalls revised	5-26-50	[illegible]
3	Corrected culvert pipe dimension, flow arrow added, wingwalls corrected and gravel blanket note revised	5-18-50	[illegible]
2	Gravel blanket under random fill [illegible] [illegible] at cutoff trench added	2-22-50	[illegible]
1	Elevations of top of dam, max. W.S., conservation pool & spillway crest revised. [illegible] of spillway crest revised. Gravel blanket added	2-22-50	BIB

REVISIONS

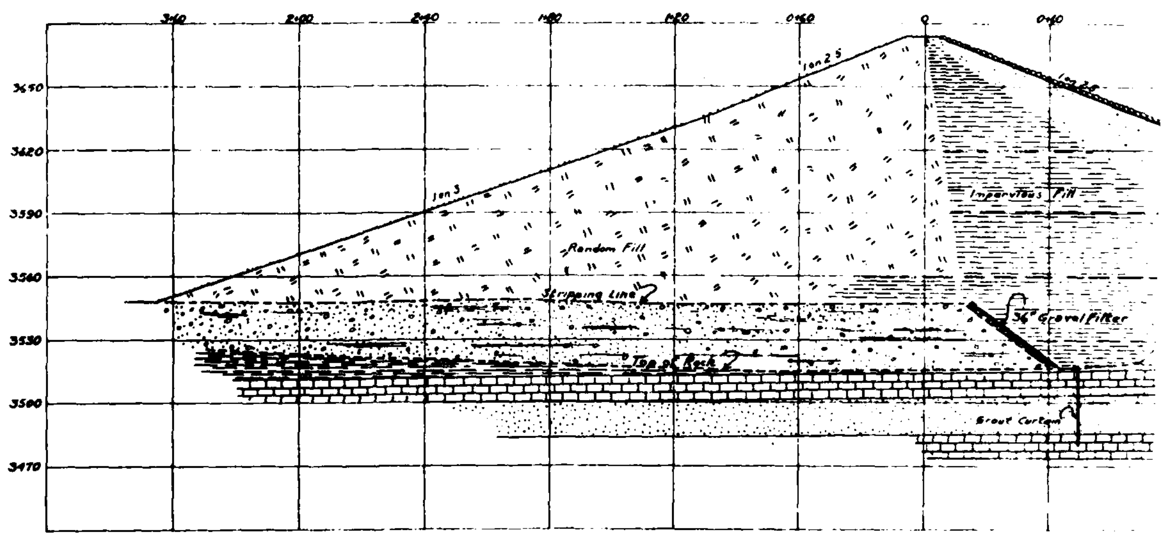
FALL RIVER BASIN
COLD BROOK DAM
COLD BROOK, SO. DAK.
GENERAL PLAN, ELEVATIONS AND SECTIONS
IN 4 SHEETS
SCALE AS SHOWN
SHEET NO.
FORT PECK DISTRICT, FORT PECK, MONTANA — SEPTEMBER 1, 19[illegible]
O.A.L.
O.A.L.
7402-[illegible] 1-2

EMBANKMENT CRITERIA AND PERFORMANCE REPORT PLATE-2 (1979)

CORPS OF ENGINEERS



Section B-B Along Centerline of Conduit

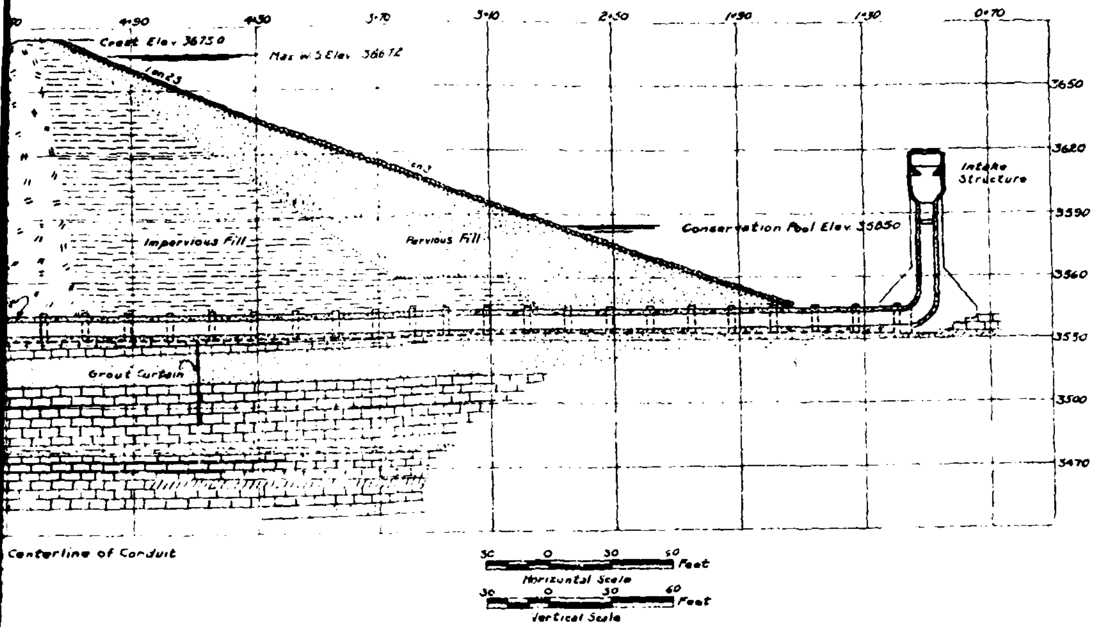


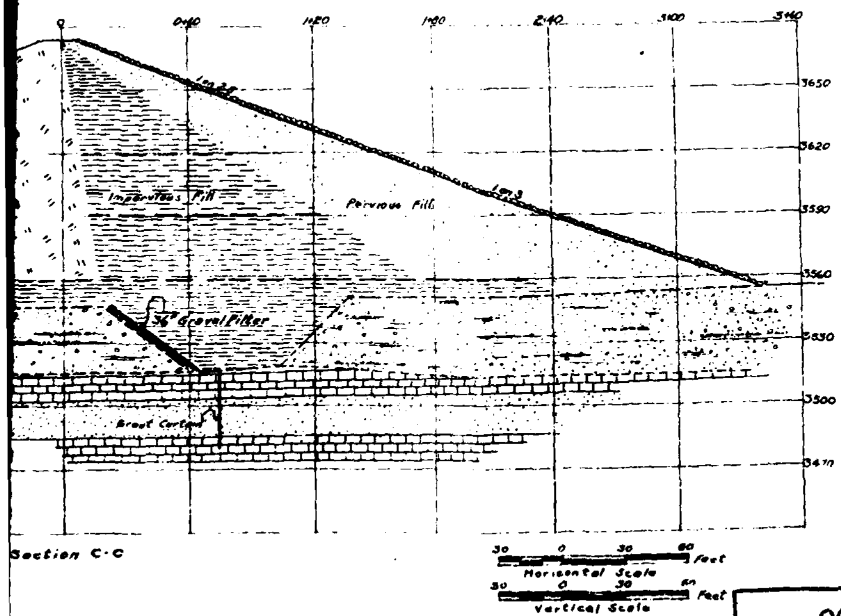
Section C-C

LEGEND

- Alluvium
- Red Sandy Shale
- Limestone
- Fine-grained buff & orange sandstone

U. S. ARMY





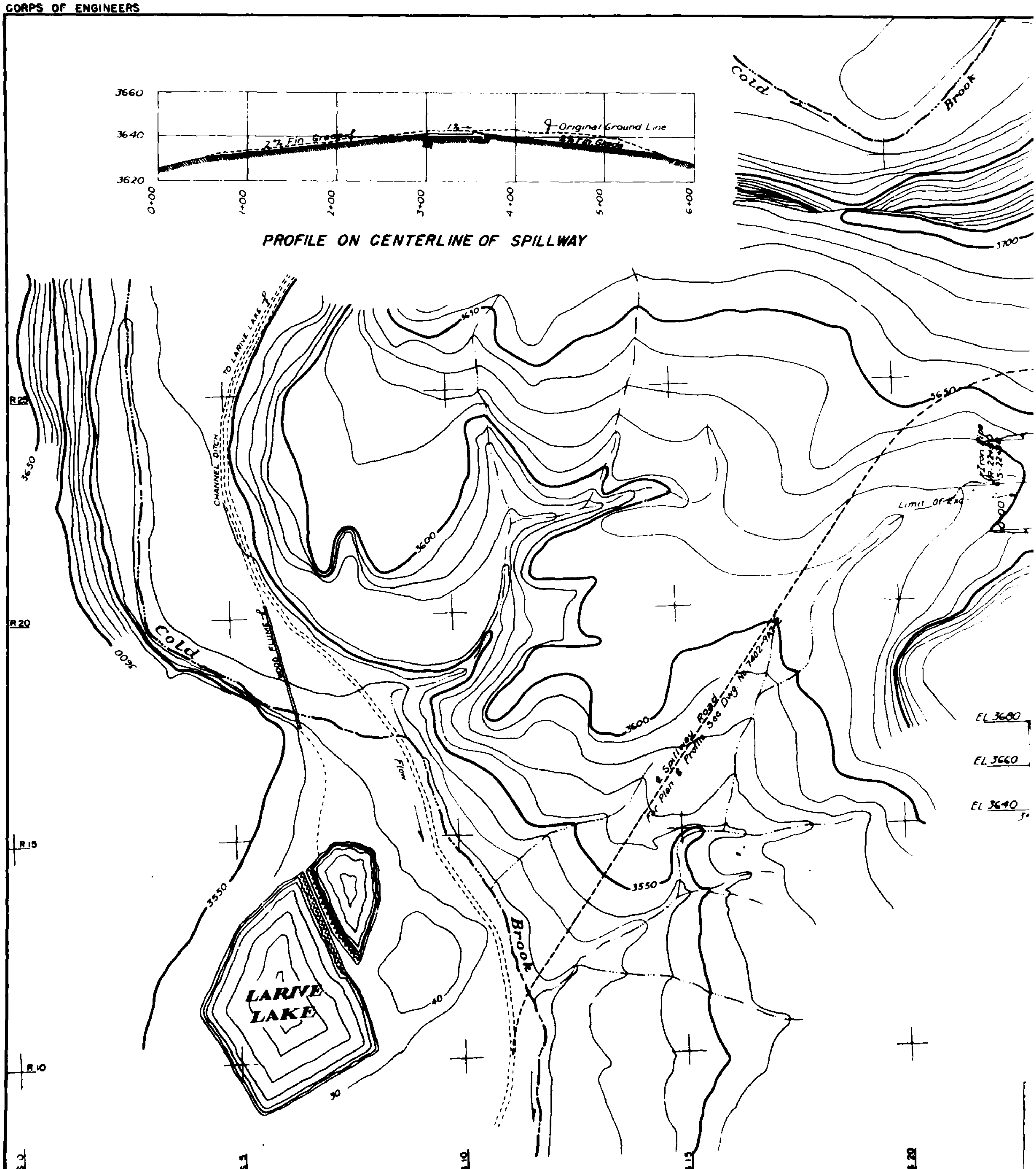
FALL RIVER BASIN
COLD BROOK DAM
HOT SPRINGS, SOUTH DAKOTA
FOUNDATION REPORT
EMBANKMENT & FOUNDATION SECTIONS
IN 4 SHEETS SCALE AS SHOWN SHEET NO 4

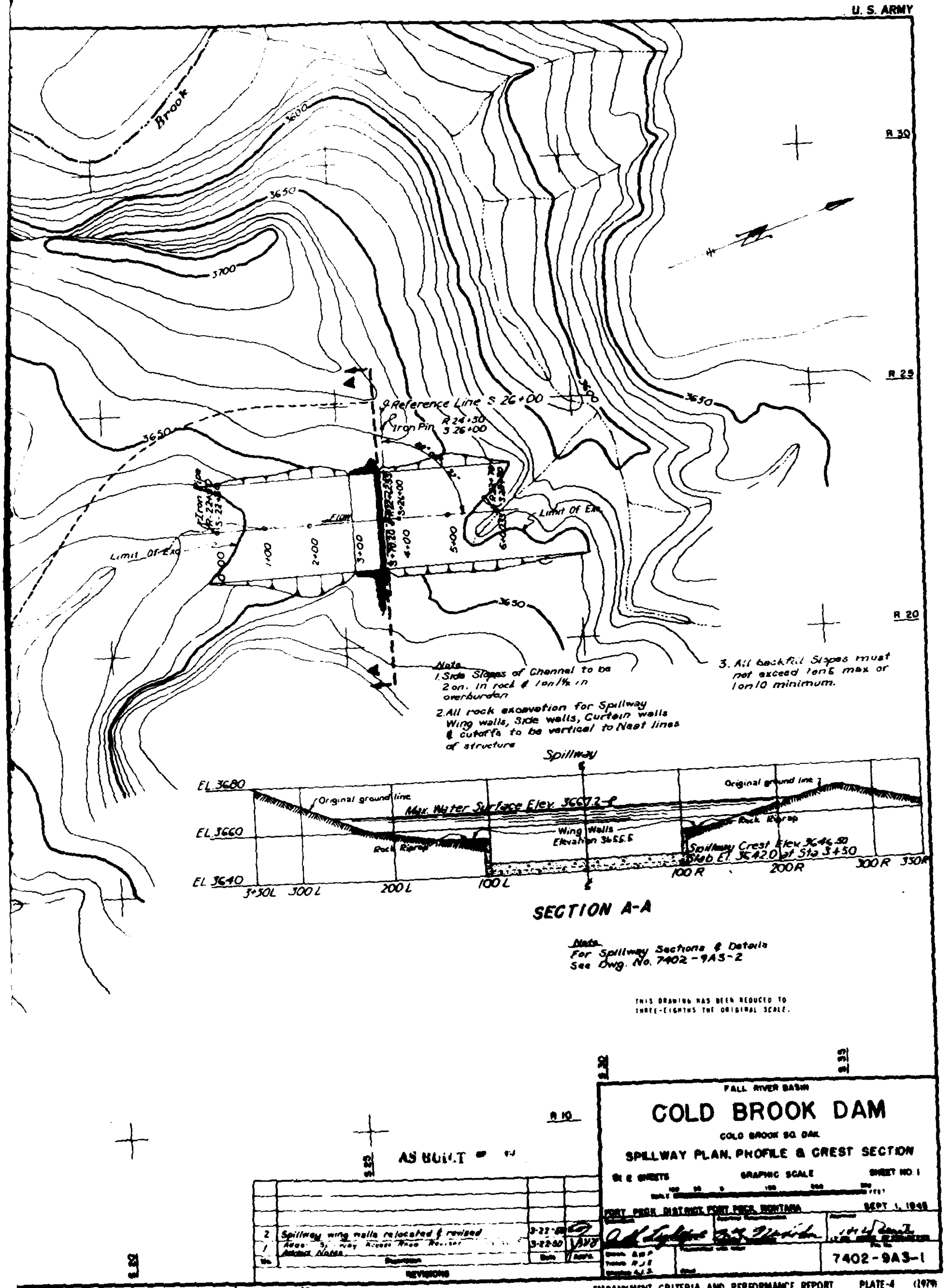
FORT PECK DISTRICT, FORT PECK, MONTANA - JANUARY 1954

7402-9.1-8

REVISIONS

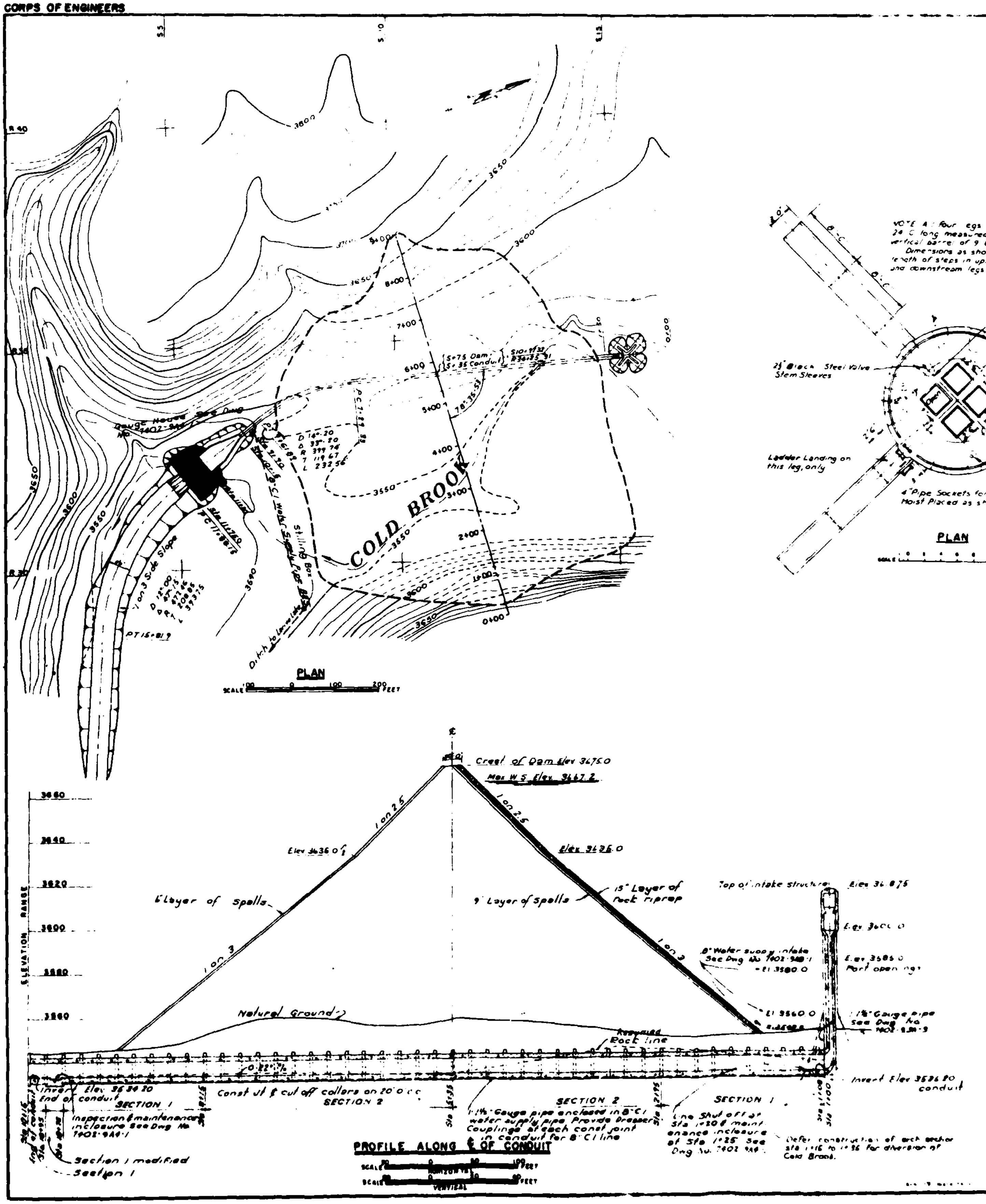
CORPS OF ENGINEERS

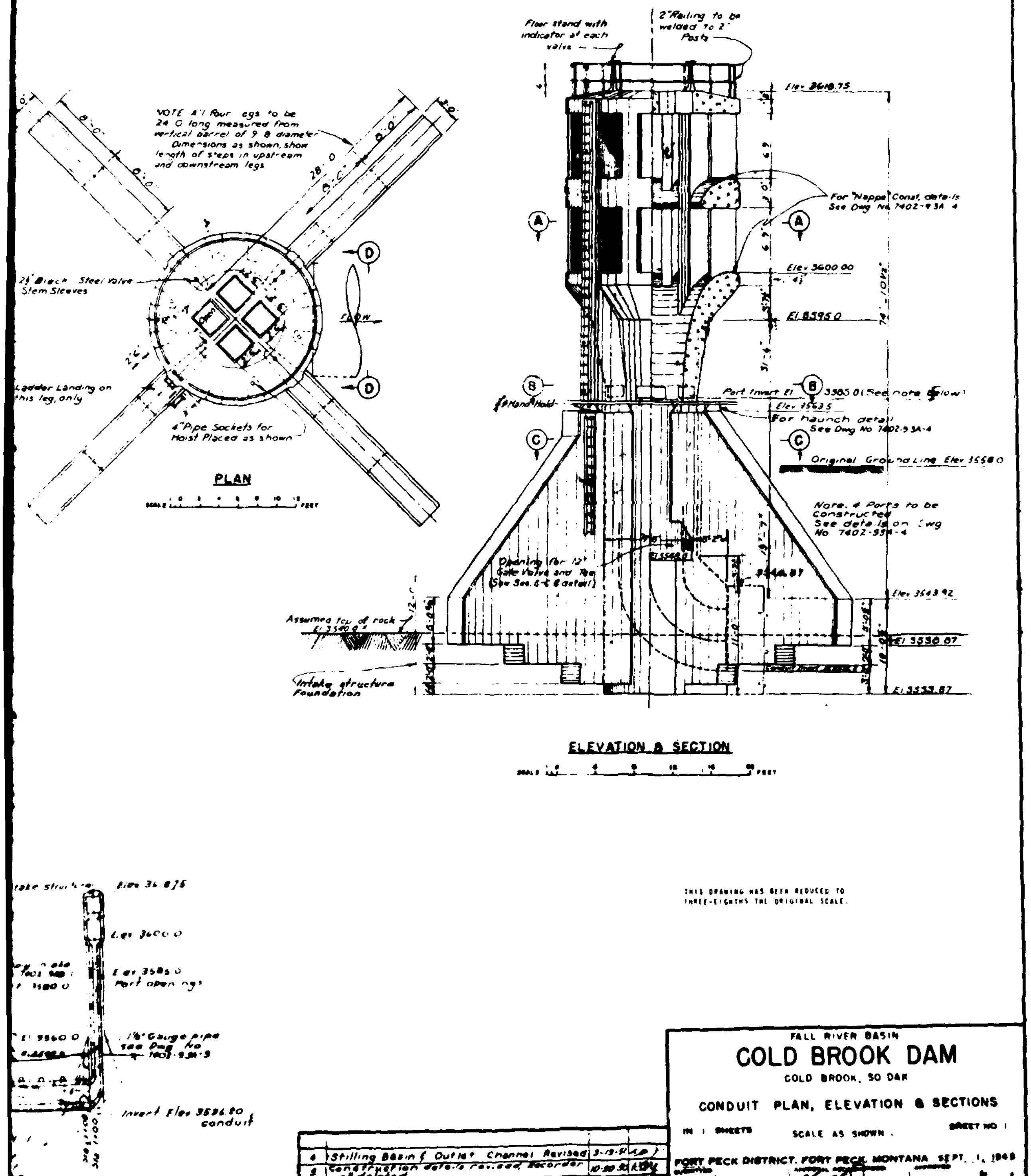




EMBANKMENT CRITERIA AND PERFORMANCE REPORT PLATE-4 (1979)

CORPS OF ENGINEERS





FALL RIVER BASIN

COLD BROOK DAM

COLD BROOK, SO DAK

CONDUIT PLAN, ELEVATION & SECTIONS

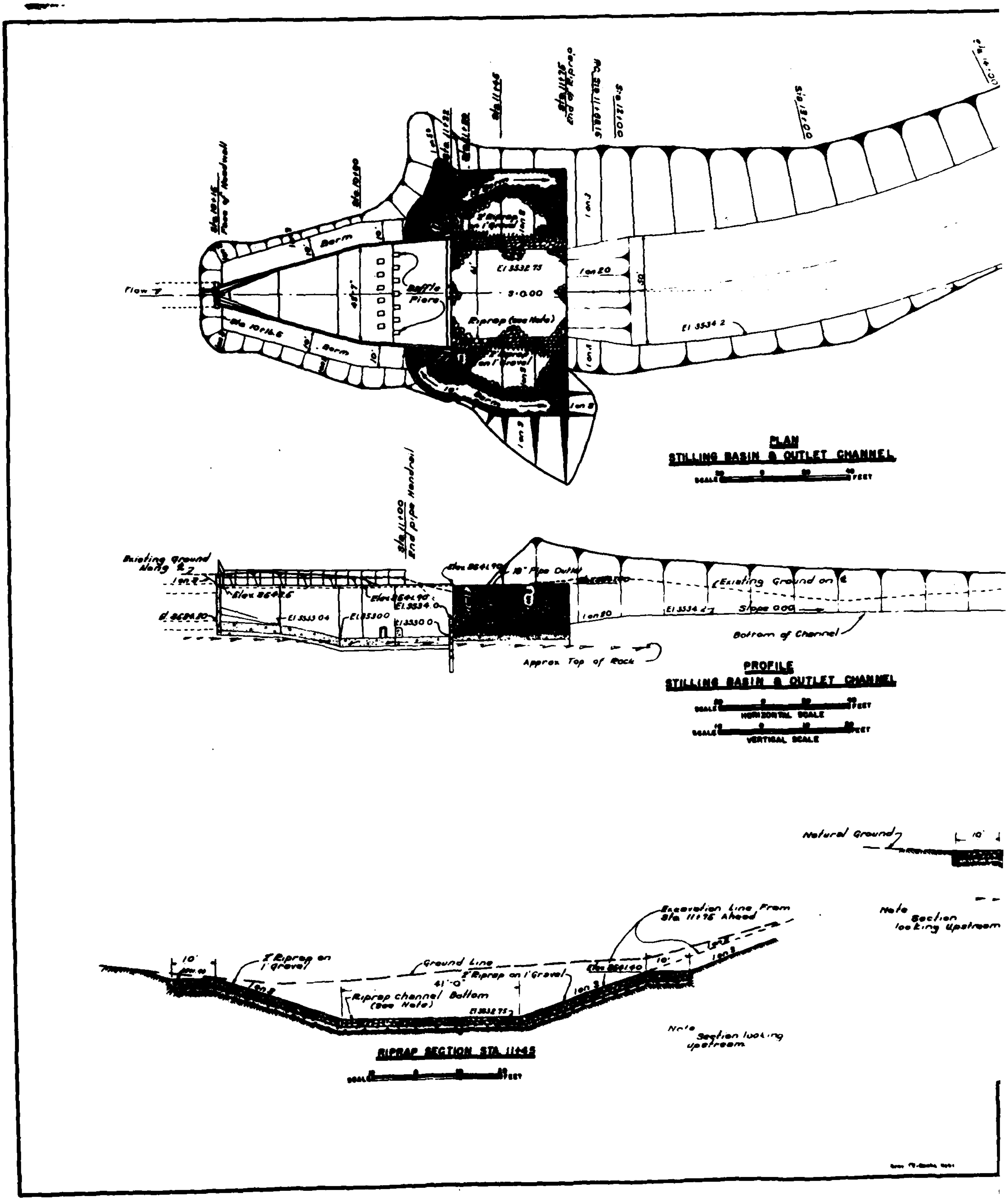
IN 1 SHEETS — SCALE AS SHOWN — SHEET NO 1

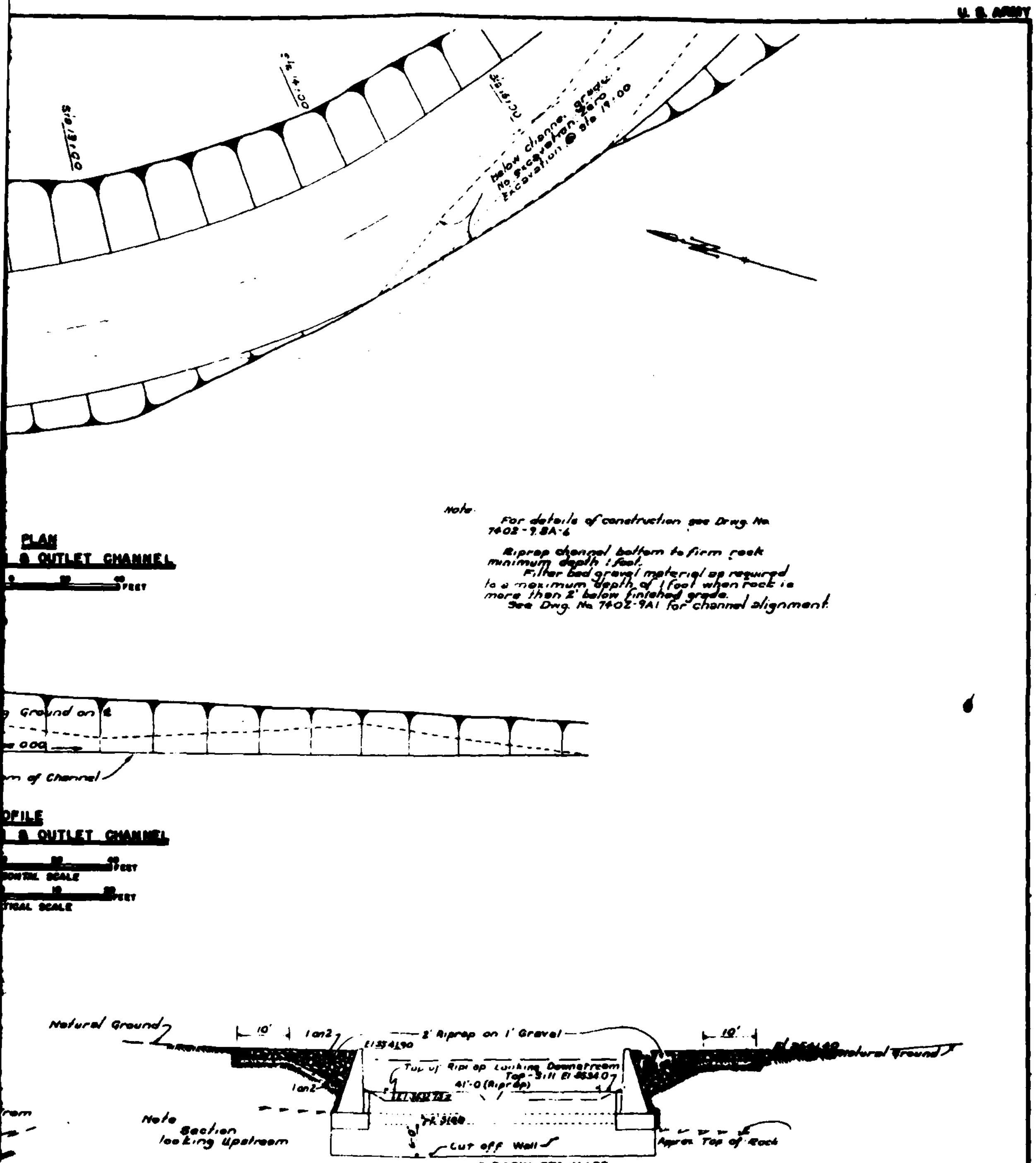
FORT PECK DISTRICT, FORT PECK, MONTANA SEPT. 1, 1949

7402-9.32-1

NO	DESCRIPTION	DATE	APP'D
4	Stilling Basin & Outlet Channel Revised	3-19-51	
3	Construction details revised, Recorder well deleted	10-20-50	
2	Rock line changed to read "Assumed rock line"	6-25-50	
1	Sheet redrawn, conduit design & structural details revised	3-22-50	

REVISIONS


Flow
Berm
Baffle Piers
Riprap (see Note)
El 3532.75
El 3534.2
1 on 20
Existing Ground on ℄
Slope 0.00
Bottom of Channel
Approx Top of Rock
18" Pipe Outlet
End pipe Handrail
El 3534.0
El 3530.0
PLAN
STILLING BASIN & OUTLET CHANNEL
PROFILE
STILLING BASIN & OUTLET CHANNEL
HORIZONTAL SCALE
VERTICAL SCALE
Natural Ground
Note
Section looking Upstream
Excavation Line From Sta 11+75 Ahead
Ground Line
2' Riprap on 1' Gravel
Riprap channel Bottom (See Note)
41'-0"
Note
Section looking upstream
RIPRAP SECTION STA. 11+45

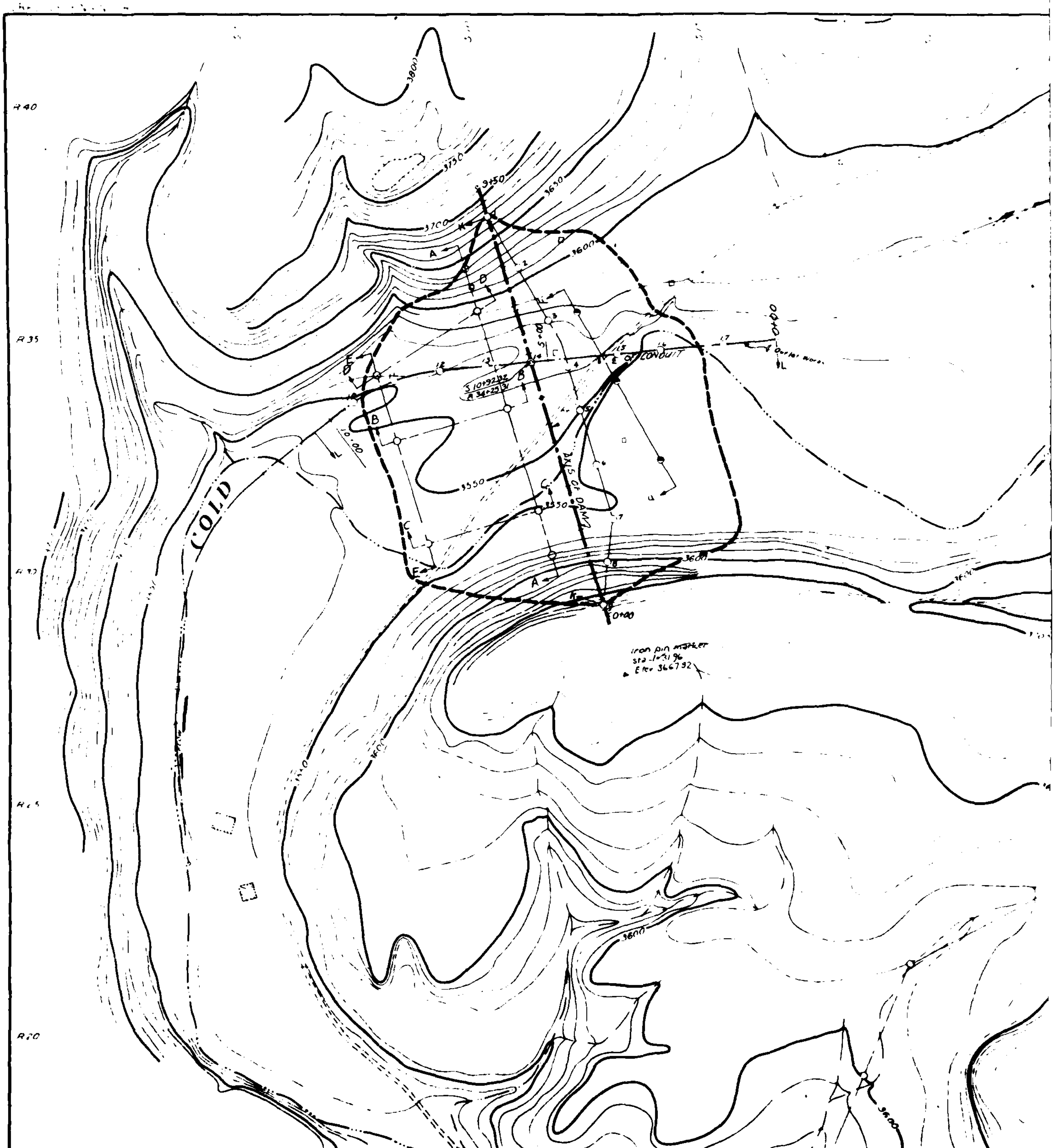


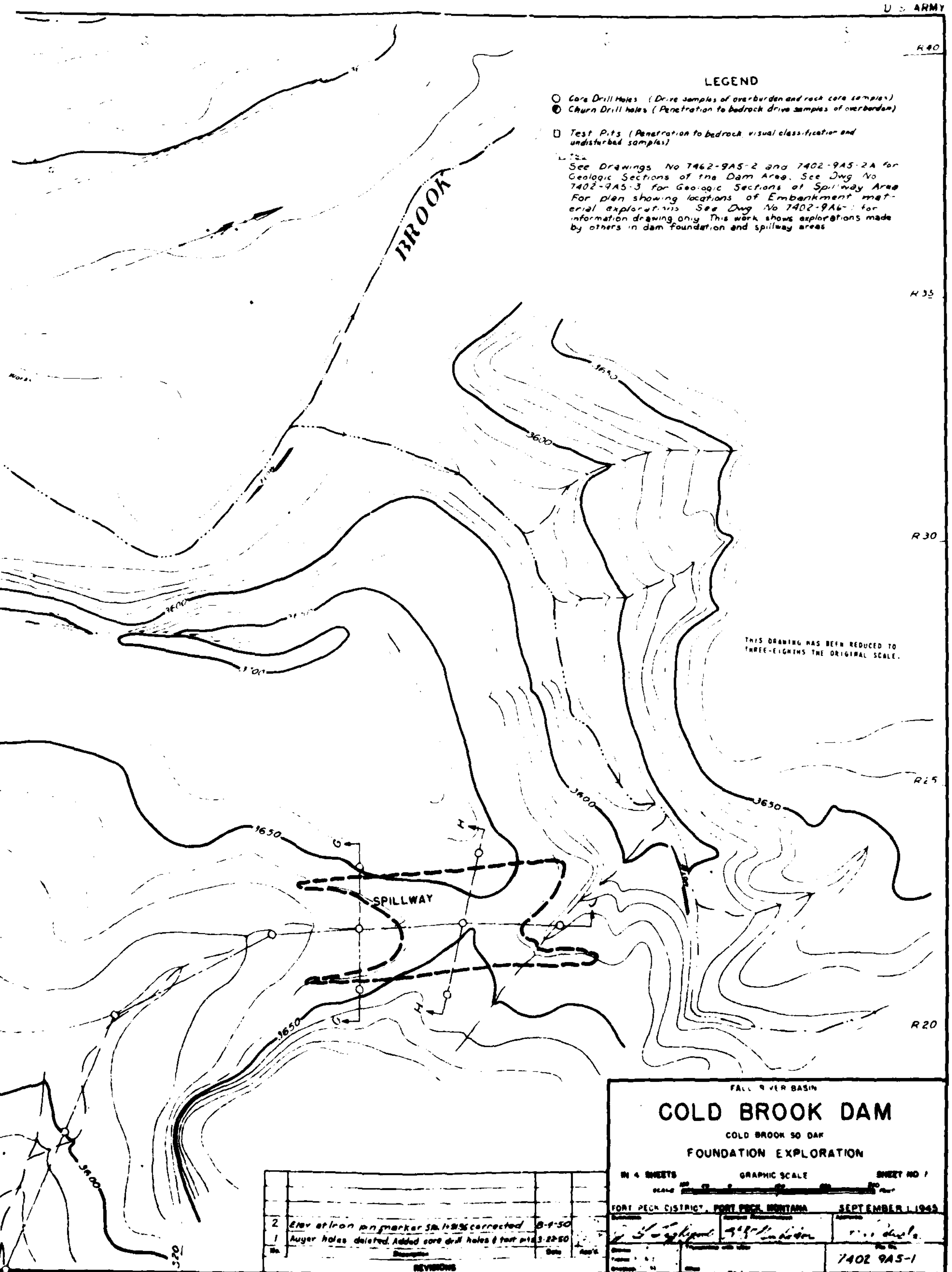
Note
For details of construction see Drwg. No. 7402-9.8A-6
Riprap channel bottom to firm rock minimum depth 1 foot.
Filter bed gravel material as required to a maximum depth of 1 foot when rock is more than 2' below finished grade.
See Dwg. No. 7402-9A1 for channel alignment.

FALL RIVER BASIN
COLD BROOK DAM
COLD BROOK, SO. DAK.
STILLING BASIN
PLAN, PROFILE AND SECTIONS
IN 2 SHEETS SCALE AS SHOWN SHEET NO. 1
FORT PECK DISTRICT, FORT PECK, MONTANA DEC. 12, 1945
7402-9.3A-5

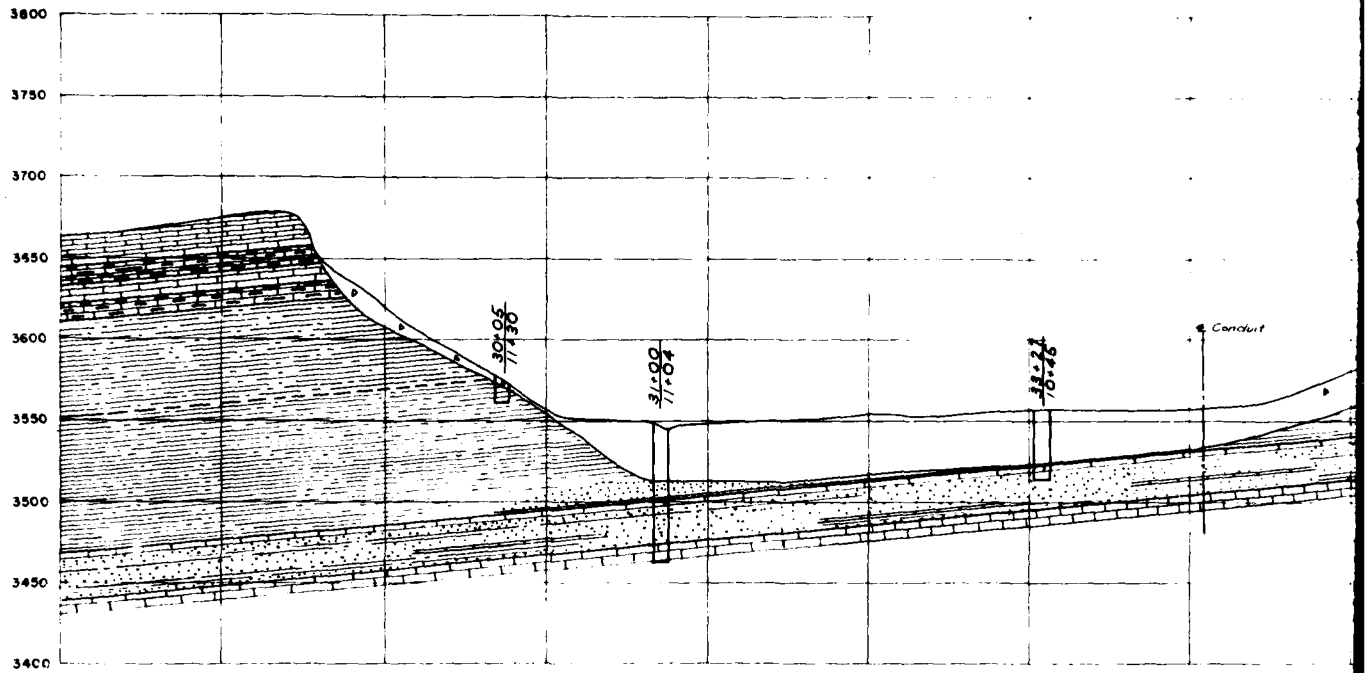
NO.	DESCRIPTION	DATE	
3	... Basin & Outlet Channel Revised.	3 1951	
2	Rock Line changed to read "Assumed Rock Line"	5-25-50	
1	Sheet redrawn, revised elev. of sill.		

REVISIONS

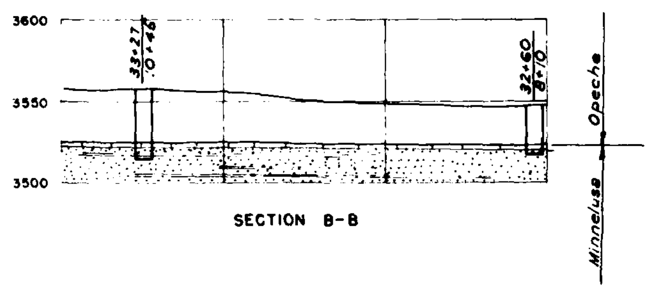

COLD
AXIS OF DAM
CONDUIT
Iron pin marker
Sta. 1+31.96
Elev. 3667.92
3800
3750
3700
3650
3600
3550
9+50
0+00
R 40
R 35
R 30
R 20



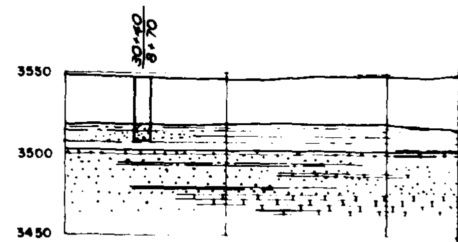
U S ARMY
LEGEND
Core Drill Holes (Drive samples of overburden and rock core samples)
Churn Drill holes (Penetration to bedrock drive samples of overburden)
Test Pits (Penetration to bedrock, visual classification and undisturbed samples)
See Drawings No 7462-9A5-2 and 7402-9A5-2A for Geologic Sections of the Dam Area. See Dwg No 7402-9A5-3 for Geologic Sections of Spillway Area. For plan showing locations of Embankment material explorations See Dwg No 7402-9A6- for information drawing only. This work shows explorations made by others in dam foundation and spillway areas
BROOK
SPILLWAY
3650
3600
R 40
R 35
R 30
R 25
R 20
THIS DRAWING HAS BEEN REDUCED TO THREE-EIGHTHS THE ORIGINAL SCALE.
2 Elev at iron pin marker Sta. corrected 8-9-50
1 Auger holes deleted. Added core drill holes & test pits 3-23-50
REVISIONS
FALL RIVER BASIN
COLD BROOK DAM
COLD BROOK SO DAK
FOUNDATION EXPLORATION
IN 4 SHEETS
GRAPHIC SCALE
SHEET NO 1
FORT PECK DISTRICT, FORT PECK, MONTANA
SEPTEMBER 1, 1949
7402 9A5-1



SECTION A-A (PARALLEL TO AXIS OF DAM)



SECTION B-B



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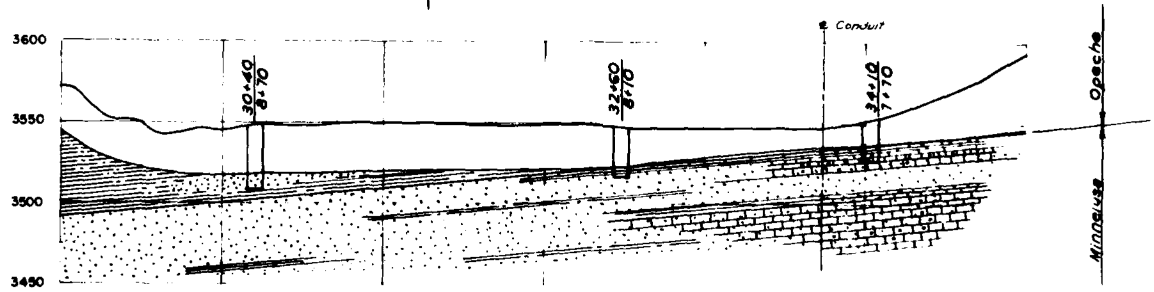
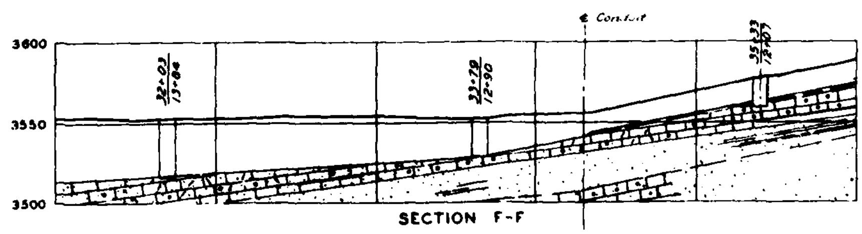
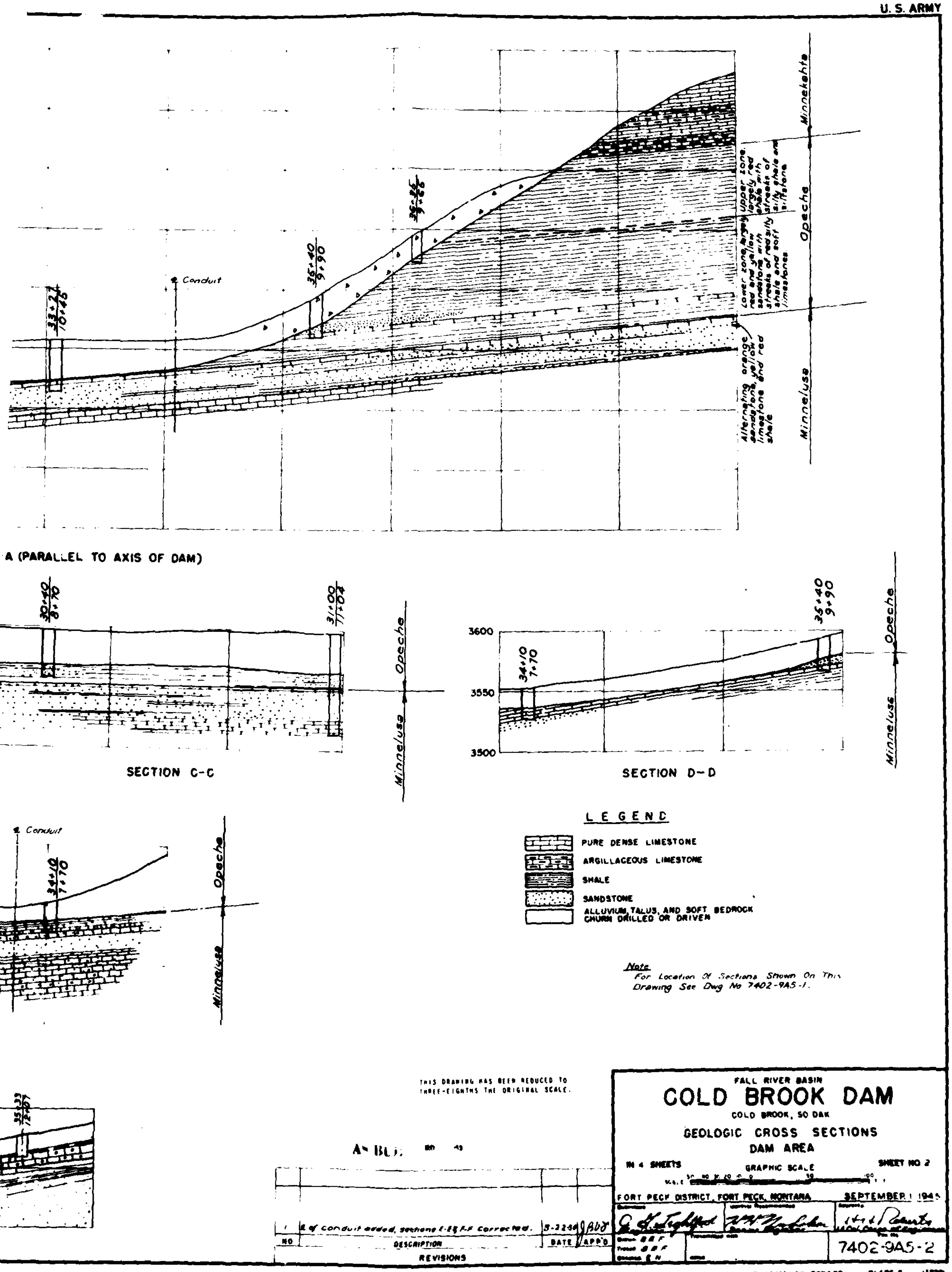


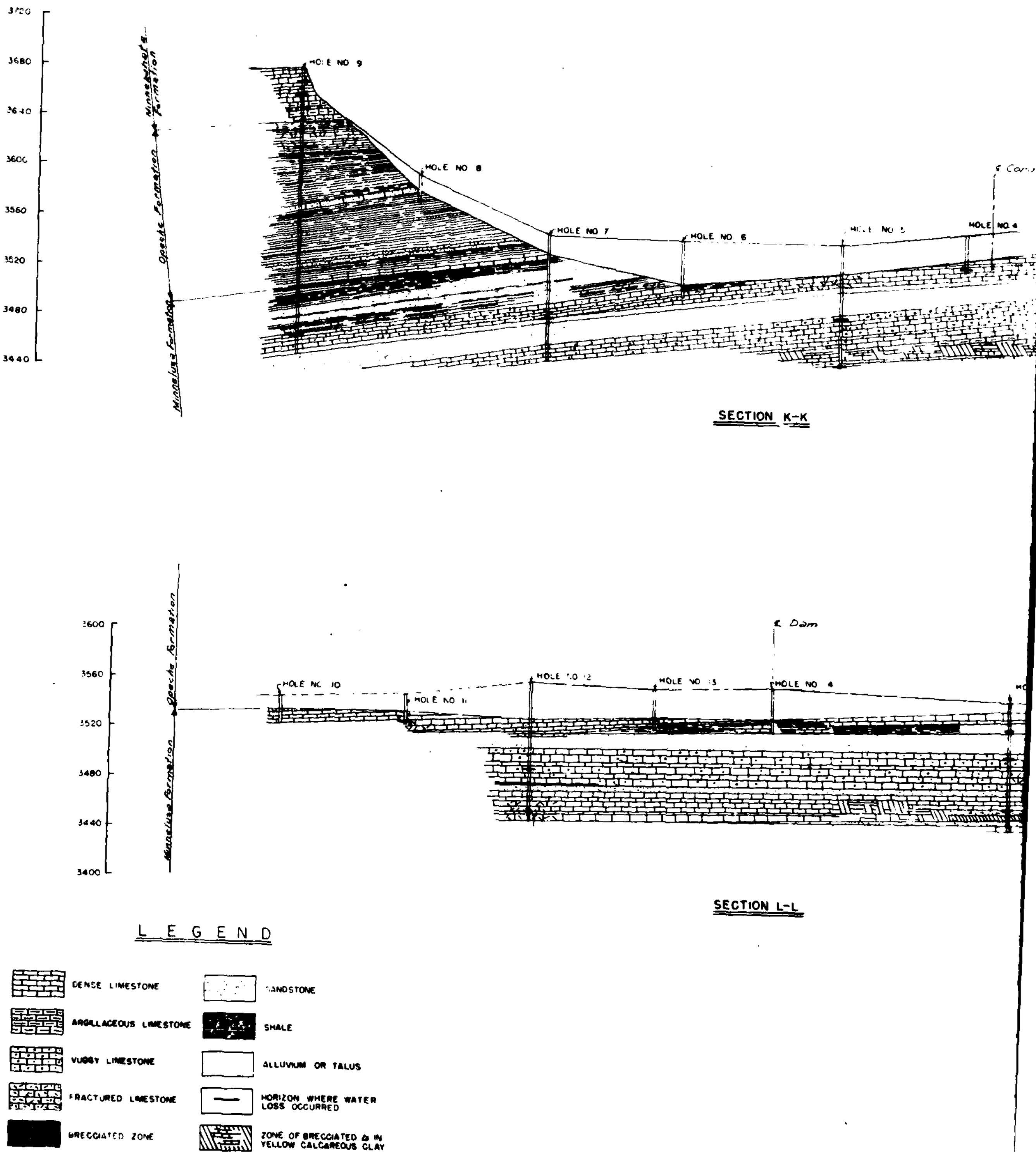
SECTION E-E

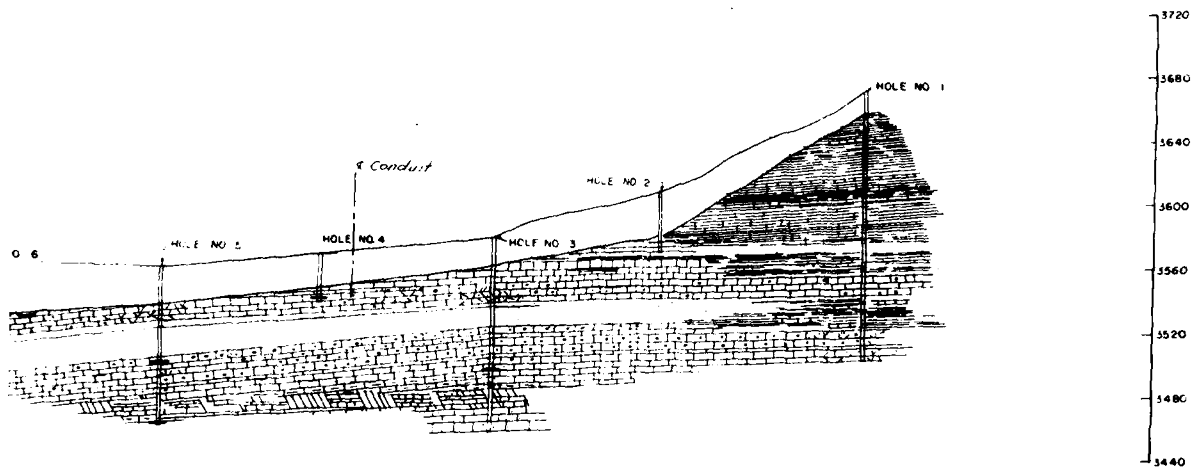


SECTION F-F

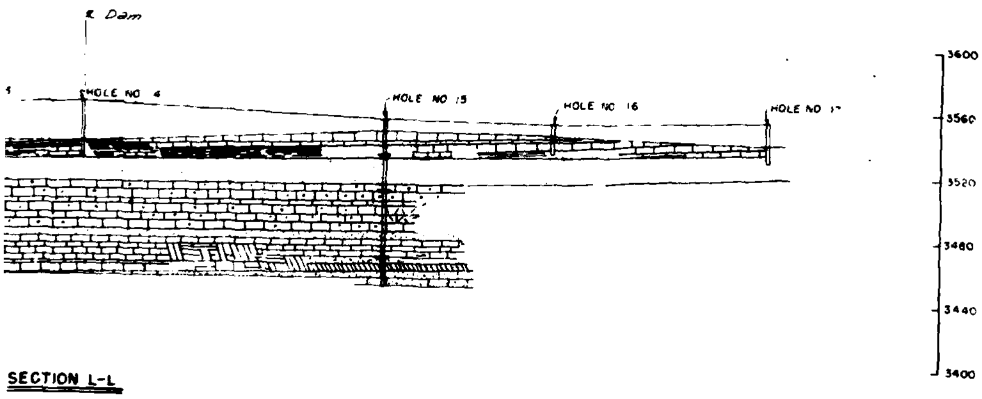

U. S. ARMY
Minnekahta
Opeche
Minnelusa
Upper zone largely red shale with streaks of silty shale and siltstone
Lower zone largely red and yellow sandstone with streaks of red silty shale and soft limestones
Alternating orange sandstone, yellow limestone and red shale
℄ Conduit
33+27 10+45
35+40 9+90
36+86 9+66
A (PARALLEL TO AXIS OF DAM)
30+40 8+70
31+00 11+04
SECTION C-C
3600
3550
3500
34+10 7+70
35+40 9+90
SECTION D-D
℄ Conduit
34+10 7+70
35+33 12+07
LEGEND
PURE DENSE LIMESTONE
ARGILLACEOUS LIMESTONE
SHALE
SANDSTONE
ALLUVIUM, TALUS, AND SOFT BEDROCK CHURN DRILLED OR DRIVEN
Note
For Location Of Sections Shown On This Drawing See Dwg No 7402-9A5-1.
THIS DRAWING HAS BEEN REDUCED TO THREE-EIGHTHS THE ORIGINAL SCALE.
1 ℄ of conduit added, sections E-E & F-F corrected.
NO DESCRIPTION DATE APP'D
REVISIONS
FALL RIVER BASIN
COLD BROOK DAM
COLD BROOK, SO DAK
GEOLOGIC CROSS SECTIONS
DAM AREA
IN 4 SHEETS
GRAPHIC SCALE
SHEET NO 2
FORT PECK DISTRICT, FORT PECK, MONTANA
SEPTEMBER 1945
7402-9A5-2

CORPS OF ENGINEERS





SECTION K-K



SECTION L-L

SCALE: 1" = 40' HORIZ. 1" = 40' VERT.

THIS DRAWING HAS BEEN REDUCED TO THREE-EIGHTHS THE ORIGINAL SCALE.

Note:
For location of sections shown on this drawing
See Dwg. No. 7402 9A5-1

NO.	DESCRIPTION	DATE	APP'D
1	Sheet added covering additional exploration	3-22-50	

REVISIONS

FALL RIVER BASIN

COLD BROOK DAM

COLD BROOK, SO. DAK.

GEOLOGIC CROSS SECTIONS

DAM AREA

IN 4 SHEETS SCALE AS SHOWN SHEET NO 3

FORT PECK DISTRICT, FORT PECK, MONTANA MARCH 22, 1950

SUBMITTED APPROVAL RECOMMENDED APPROVED

CHIEF ENGINEERING DIVISION CORPS OF ENGINEERS

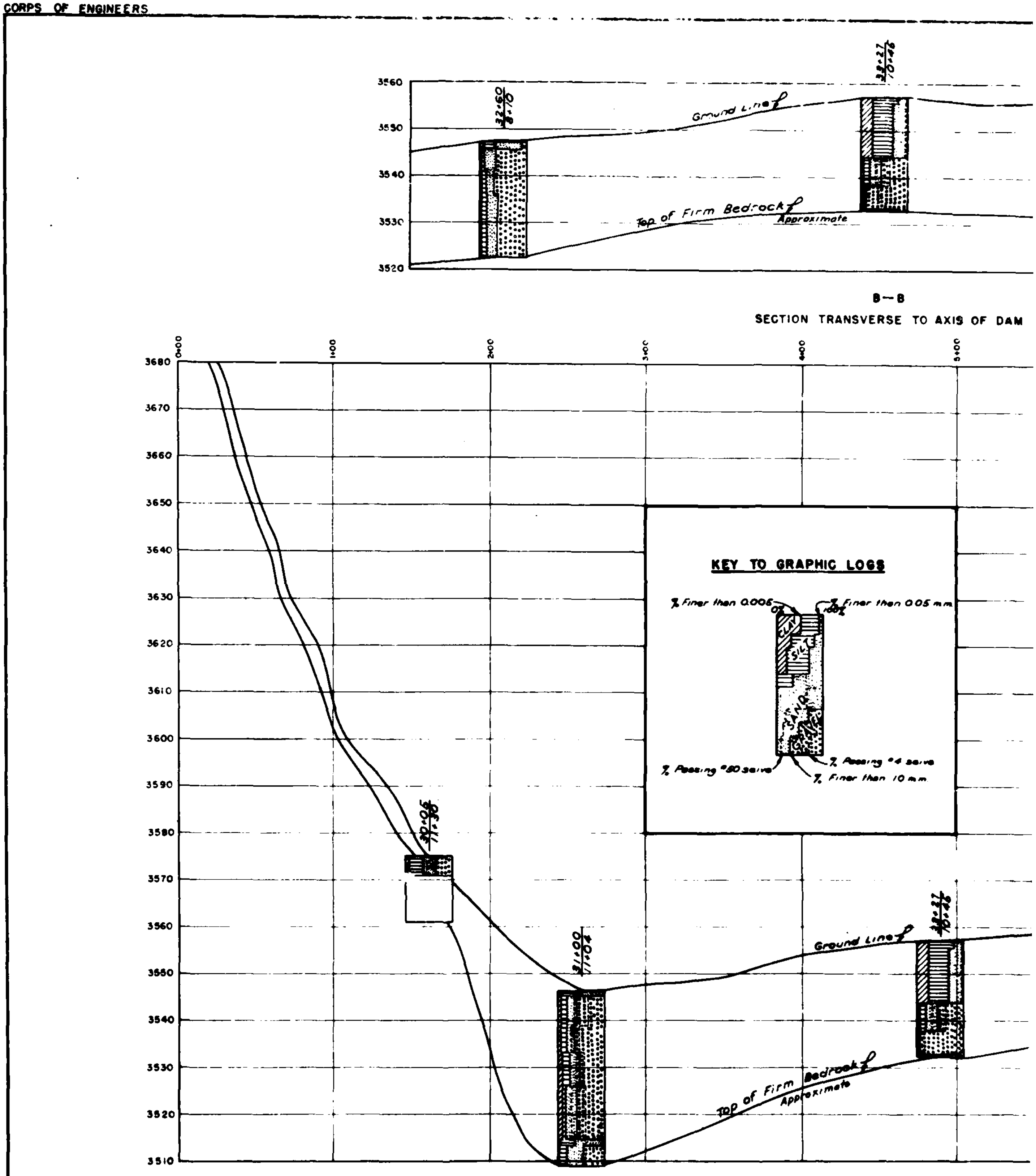
DRAWN J.B.H. TRANSMITTED WITH LETTER

TRACED J.E.H. FILE NO.

CHECKED L.H. DATED

7402-9A5-2A

CORPS OF ENGINEERS

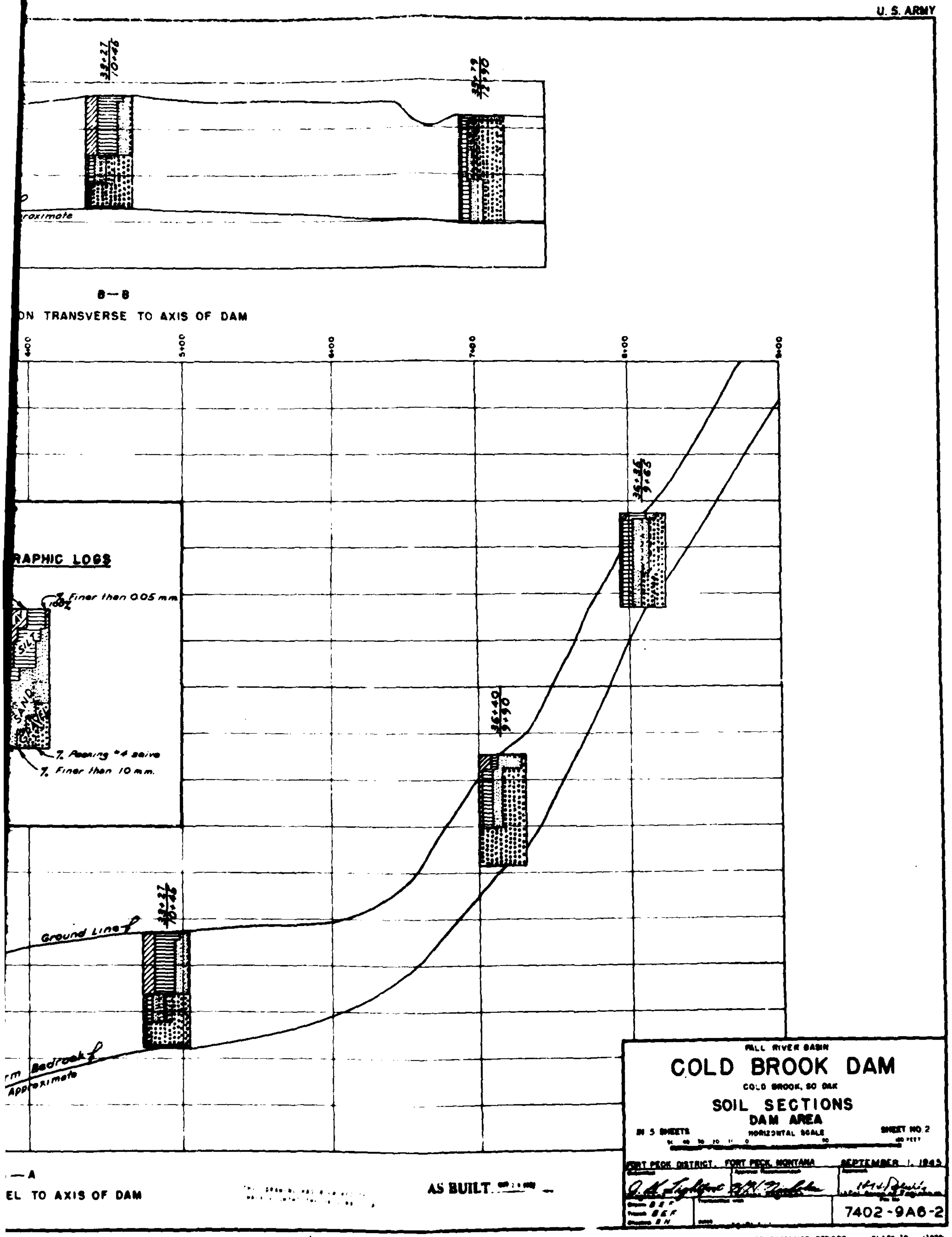


B — B

SECTION TRANSVERSE TO AXIS OF DAM

A — A

SECTION PARALLEL TO AXIS OF DAM


U. S. ARMY
B—B
ON TRANSVERSE TO AXIS OF DAM
RAPHIC LOGS
% Finer than 0.05 mm.
100%
% Passing #4 sieve
% Finer than 10 mm.
SILT
SAND
36+40
9+90
33+27
10+46
Ground Line
Bedrock
Approximate
—A
EL TO AXIS OF DAM
AS BUILT
FALL RIVER BASIN
COLD BROOK DAM
COLD BROOK, SO DAK
SOIL SECTIONS
DAM AREA
IN 5 SHEETS
HORIZONTAL SCALE
SHEET NO. 2
FORT PECK DISTRICT, FORT PECK, MONTANA
SEPTEMBER 1, 1945
7402-9A6-2

SUMMARY OF SOIL TEST RESULTS FROM COLD B[illegible]

Depth (feet)	Character of Material	Atterberg Limits LL	PI	Mechanical Analysis Results Percent Passing .005 mm.	.05 mm.	1.0 mm.	#4 sieve	Optimum Compaction Dry Wt #/cu ft	Moisture %	Initial Specime[n] Dry Wt #/cu ft
Borrow Area Sta. 14 + 10 Range 35 + 70 Sampled from cutbank.										
0-4'	Sand & gravel	23	6	8	25	50	62	Field Sample		
4-7'	" "	29	10	12	32	48	57	" "		
7-14'	Red sandy soil	18	3	10	36	87	88	" "		
				11	33	64	71	" "		
				16	47	93	100	122.0	10.7	
0-14'	Composite	21	5	17	47	90	100			108.2
				17	45	90	100			107.2
				16	51	95	100			120.2
				16	48	93	100			121.0
Borrow Area Sta 17 + 90 Range 38 + 20 Test Pit										
0-6'	Sand & gravel	32	12	14	35	54	61	Field Sample		
6-12'	" "	25	9	12	38	63	72	" "		
12-22'	" "	21	6	5	16	27	36	" "		
				8	28	42	53	" "		
				13	51	83	100	121.0	10.0	
0-22'	Composite	29	9	18	58	91	100			113.7
				13	52	82	100			124.5
Borrow Area Sta 11 + 75 Range 36 + 85 Test Pit										
	Clavey gravel	39	17	21	55	70	76	Field Sample		
0-6'				30	76	95	100	110.0	15.2	
	Bulk Sample			30	77	96	100			97.0
				30	77	95	100			102.6
				29	76	96	100			111.0
Borrow Area Sta 12+ 95 Range 32 + 45 Test Pit										
0-7'	Gravel	22	6	3	12	22	35	Field Sample		
7-13'	Gravel	23	9	3	8	16	28	" "		
				3	10	19	33	" "		
0-13'	Composite	22	8	10	28	60	100	125.2	9.6	
				13	36	70	100			118.1

Direct Shear				Consolidation				Permeability	
ximum		Ultimate		Percent Consolidation				Cm	Feet
	Tan		Tan					Per	Per
	Ø	C	Ø	1T	2T	4T	7T	Sec	Day
20	0.50	0.20	0.50						
10	0.47	0.10	0.47						
aked at 7 Ton				1.6	2.2	3.0	3.8-3.9	$6.58x10^{-7}$	0.00186
06	0.58	0.00	0.57					$5.25x10^{-6}$	0.0149
.12	0.44	0.12	0.44						
.09	0.46	0.09	0.46					$6.34x10^{-7}$	0.00179
.16	0.72	0.09	0.69						

Depth (feet)	Character of Material	Atterberg Limits LL	Atterberg Limits PI	Mechanical Analysis Results, Percent Passing .005 mm.	.05 mm.	1.0 mm.	#4 sieve	Optimum Compaction Dry Wt #/cu ft	Optimum Compaction Moisture %	Initial Specim Dry Wt. #/cu ft
Foundation Test Pit Sta. 2 + 25 Range 24 + 50 Top Elevation 3539.4 Located on proposed axis to right of streambed.										
	Sandy loam	19	1	9	40	100	100			85.4
0-3'	Undisturbed	23	6	13	58	100	100			84.0
				18	44	98	100	110.0	13.4	
				15	46	99	100			110.3
	Sandy loam			16	46	99	100			109.7
0-3'	Bulk Sample	23	6	13	44	97	100			108.6
				14	44	98	100			88.9
				14	42	93	95	Field Sample		
				11	29	66	100	129.8	9.0	
	Gravel			12	26	64	100			117.[illegible]
3-12'	Bulk Sample	19	2	12	29	66	100			118.9
				2	2	5	8	Field Sample		
				24	56	83	100	118.7	11.3	
				22	57	89	100			105.8
	Gravel			26	59	88	100			111.6
12-14'	Bulk Sample	26	10	25	56	83	100			103.2
				3	8	12	14	Field Sample		
				32	77	97	100	122.5	12.2	
	Opeche shale mixed			30	72	94	100			117.0
	with rocks			32	73	96	100			111.7
14-17'	Bulk Sample	26	10	32	72	91	100			116.9
				33	78	97	100			97.8
				15	35	46	49	Field Sample		
				30	77	96	100	122.8	11.0	
				28	72	95	100			116.7
	Decomposed			31	72	95	100			110.0
17-18'	Opeche shale	25	10	28	66	88	100			115.8
				30	76	96	100			99.6
				19	46	57	60	Field Sample		

Mechanical analysis results are from specimens tested for o

FROM COLD BROOK DAM

e	Initial Conditions Specimens Tested Dry Wt. #/cu ft	Moisture %	Direct Shear Maximum C	Maximum Tan ∅	Ultimate C	Ultimate Tan ∅	Consolidation Percent Consolidation 1T	2T	4T	7T	Permeability Cm Per Sec	Feet Per Day
	85.4	4.6	0.16	0.64	0.00	0.63						
	84.0	4.4	Soaked at 7 Ton				9.5	13.8	17.8	20.4-20.5		
	110.3	12.8	0.00	0.61	0.00	0.57						
	109.7	13.0	0.00	0.63	0.00	0.60						
	108.6	13.3	Soaked at 7 Ton				1.0	1.6	2.3	3.50-3.56		
	88.9	12.7									1.955×10^{-3}	5.52
	117.2	7.1	0.05	0.70	0.05	0.70						
	118.9	6.6									1.45×10^{-4}	0.41
	105.8	10.6	0.03	0.58	0.03	0.58						
	111.6	14.6	0.35	0.61	0.22	0.61						
	103.2	10.7									1.17×10^{-4}	0.332
	117.0	12.9	0.25	0.63	0.17	0.61						
	111.7	15.4	0.26	0.60	0.20	0.57						
	116.9	13.0	Soaked at 7 Ton				1.2	2.6	4.4	6.2-6.4		
	97.8	13.7									3.74×10^{-5}	0.106
	116.7	11.1	0.00	0.57	0.00	0.56						
	110.0	10.7	0.00	0.51	0.00	0.51						
	115.8	12.5	Soaked at 7 Ton				0.4	2.3	4.3	6.40-6.44	1.33×10^{-4}	0.376
	99.6	11.0										

tested for other properties except those marked field sample.

SUMMARY OF SOIL TEST RESULTS FROM COLD B

Depth (feet)	Character of Material	Atterberg Limits LL	Atterberg Limits PI	Mechanical Analysis Results, Percent Passing .005 mm.	.05 mm.	1.0 mm.	#4 sieve	Optimum Compaction Dry Wt #/cu ft	Optimum Compaction Moisture %	Initial Specim Dry Wt #/cu f
Exposed gravelly face at Sta 6 + 50 below axis on left abutment.										
	Gravelly			28	48	73	100	118.5	10.8	
0-30'	alluvium			4	8	13	18	Field Sample		
	Bulk Sample			18	46	73	100			95.1
				18	48	74	100			106.7
Test Pit Sta 11 + 54 Range 34 + 44 Undisturbed Samples										
1.2-1.8'		37	13	28	87	100	100	Undisturbed		71.7
2.3-2.9'		40	10	28	76	100	100	"		69.2
3.4-4.0'		45	17	26	83	100	100	"		68.1
4.3-4.9'		37	16	24	76	98	100	"		72.8
5.0-5.6'		33	12	19	70	99	100	"		74.8
5.6-6.2'		32	12	21	70	99	100	"		87.8
6.2-6.9		34	14	22	80	99	100	"		83.6
7.0-7.8'		22	5	19	68	100	100	"		74.9
8.0-8.8'		37	15	25	81	99	100	"		71.7
8.8-9.5'		25	8	27	83	99	100	"		80.5
10.5-11.2'		31	12	20	65	100	100	"		76.5
11.2-12.2'		26	8	13	70	100	100	"		88.5

'ROM COLD BROOK DAM

Initial Conditions Specimens Tested		Direct Shear				Consolidation Percent Consolidation				Permeability	
Dry Wt	Moisture	Maximum		Ultimate						Cm	Feet
			Tan		Tan					Per	Per
#/cu ft	%	C	Ø	C	Ø	1T	2T	4T	7T	Sec	Day
95.1	10.4									1.51×10^{-4}	0.427
106.7	10.5									3.38×10^{-5}	0.0957
71.7	20.6	0.00	0.53	0.00	0.53	4.4	11.3	18.2	23.6		
69.2	10.8	0.10	0.55	0.00	0.55	0.7	2.3	6.8	13.0		
68.1	11.0	0.00	0.53	0.00	0.50	1.5	2.2	8.6	17.9		
72.8	9.5	0.00	0.57	0.00	0.57	2.9	7.6	14.7	20.4		
74.8	7.2	0.00	0.60	0.00	0.56	2.4	7.8	13.8	17.6		
87.8	6.8	0.00	0.62	0.00	0.59	2.2	6.0	11.2	15.0		
83.6	8.7	0.00	0.56	0.00	0.53	0.5	1.4	5.6	10.1		
74.9	7.4	0.00	0.55	0.00	0.53	1.2	4.1	9.5	14.6		
71.7	9.1	0.00	0.58	0.00	0.56	2.2	6.8	14.5	22.4		
80.5	10.0	0.20	0.42	0.10	0.43	4.5	8.5	14.2	18.5		
76.5	6.7	0.00	0.57	0.00	0.54	3.4	8.4	14.7	18.6		
88.5	7.9	0.00	0.62	0.00	0.62	0.5	1.5	3.8	7.2		

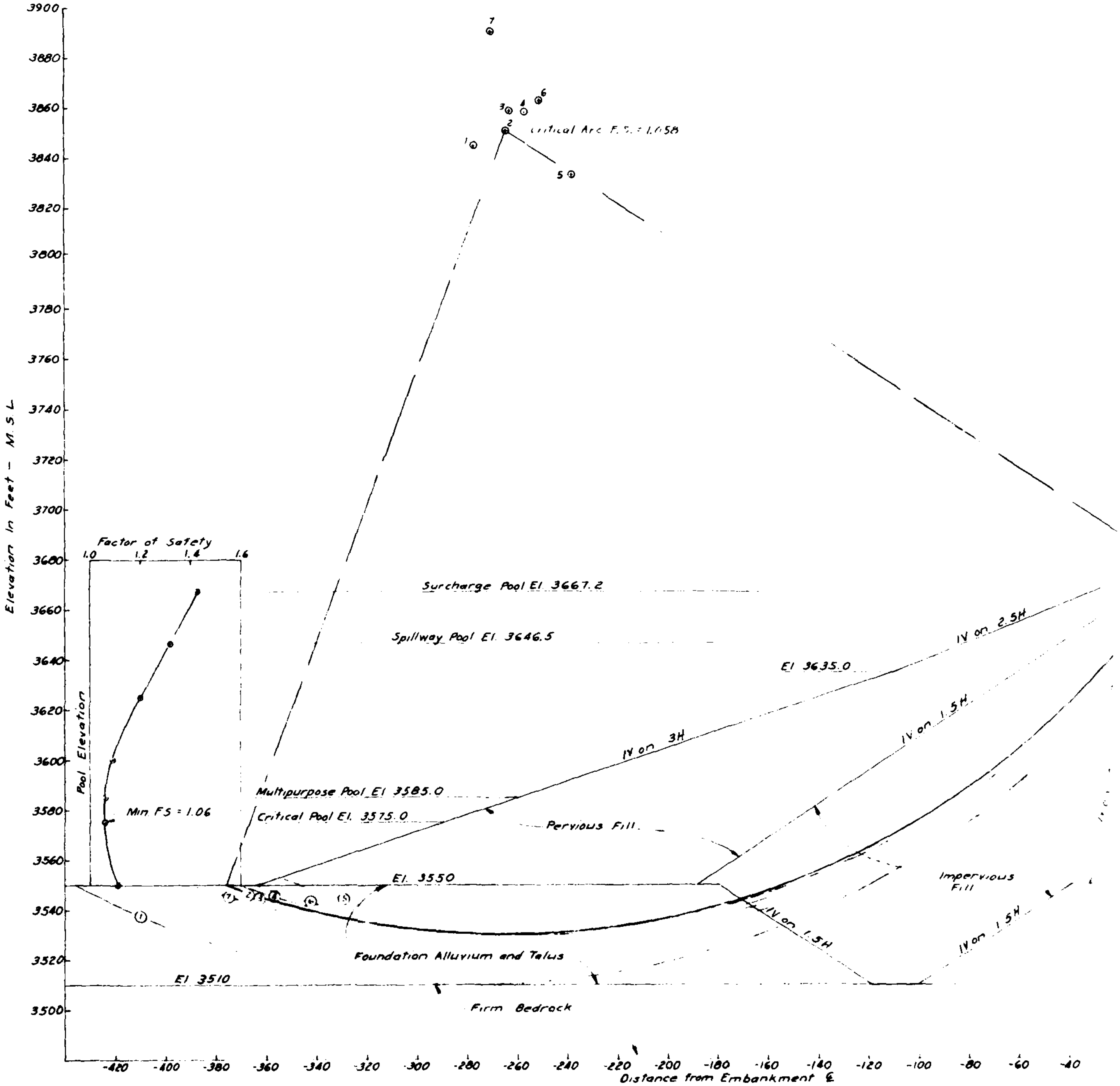


FIGURE 1

SCALE: 1 INCH = 20 FEET

Adopted Strengths								
Material	Unit Weight (Kcf)		Lower "[illegible]" Envelope			Upper "R" Envelope		
	γ Moist	γ Sat'd	Coh (KSF)	[illegible]	φ (Deg.)	Coh (KSF)	Tan φ	φ (Deg.)
Pervious and Random Fill	0.120	0.125	0	[illegible]	31.0°	0	0.6	31.0°
Impervious Fill	0.120	0.125	0	0.50	26.6°	0.50	.25	14.0°
Foundation Alluvium & Talus	0.120	0.125	0	0.50	26.6°	0.50	.25	14.0°

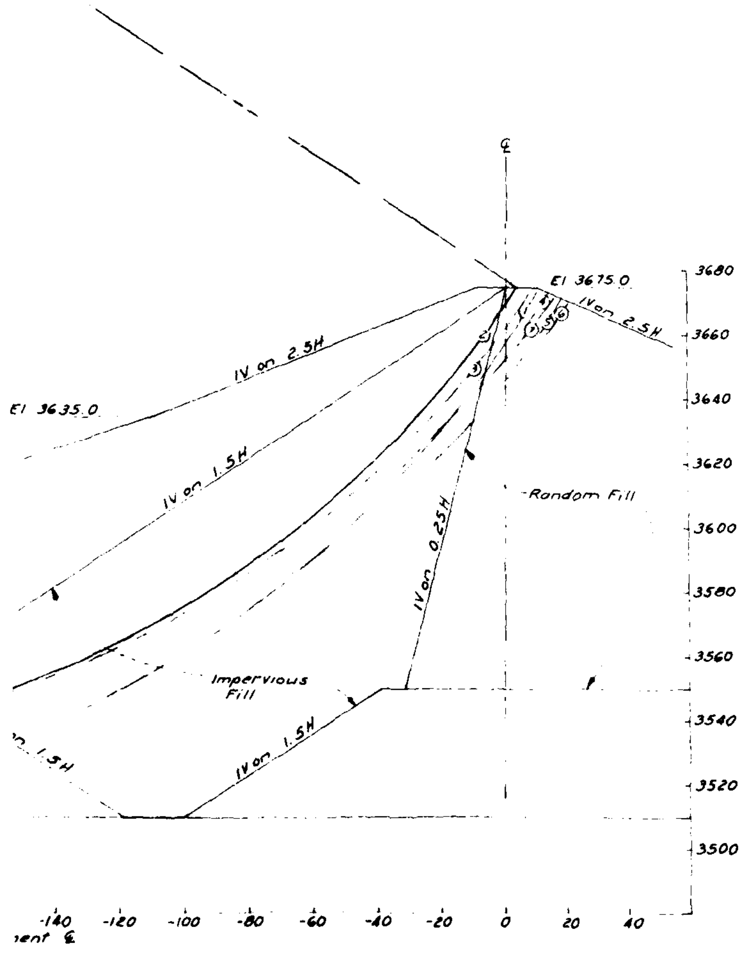
FIGURE 2

Summary of Slip Circle Analysis								
Pool Elev.	Arc Base Elevation							
	3510	3530	3550	3570	3590	3610	3630	3650
3550	1.11 [1]	1.12	1.59	1.60	1.613	1.62	1.62	
3575	1.08	* 1.06 [2]	1.35	1.56	1.613	1.62	1.62	
3585	1.09	1.06 [3]	1.30	1.43	1.613	1.62	1.62	
3600	1.13	1.09 [4]	1.28	1.31	1.465	1.62	1.62	
3625	1.24	1.20 [5]	1.38	1.35	1.336	1.38	1.62	
3646.5	1.38	1.32 [6]	1.55	1.52	1.486	1.41	1.36	
3667.2	1.50	1.43 [7]	1.70	1.70	1.642	1.67	1.53	1.51

FIGURE 3

Summary of Critical Arc Data					
Partial Pool Elevation	Critical Arc Number	Arc Base Elev.	Coordinates of Arc Center		Factor of Safety
			Horizontal	Vertical	
3550	·	3510	-277.1	3845.0	1.11
3575	2	3530	-264.1	3853.1	1.06 *
3585	3	3530	-262.9	3859.0	1.06
3600	4	3530	-257.0	3858.4	1.09
3625	5	3530	-238.5	3833.5	1.20
3646.5	6	3530	-251.3	3863.0	1.32
3667.2	7	3530	-270.4	3890.6	1.43

FIGURE 4



Notes:

1. In Figure 3 the factors of safety above and to the right of the heavy line are not influenced by that particular pool elevation. These values have not been considered in evaluating the critical factor of safety.
2. Factors of safety in Figure 3 appended with a number appear in Figure 4 with the appended number as the critical arc number. This same number is used in Figure 1 to denote arc centers and arcs.
3. * Denotes lowest factor of safety.
4. Required factor of safety is 1.2 at spillway pool and 1.0 at surcharge pool. Actual factors of safety for these pools are 1.32 and 1.43 respectively.
5. For hand run computations of the critical arc see Plate C-2.

THIS DRAWING HAS BEEN REDUCED TO THREE-EIGHTHS THE ORIGINAL SCALE.

DATE	DESCRIPTION	MADE	APPR'D

REVISIONS

U. S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA

FALL RIVER BASIN, S.D.
COLD BROOK LAKE
STABILITY RE-EVALUATION
SUDDEN DRAWDOWN CASE
(COMPUTER SUMMARY)

DESIGNED BY: DRAWN BY: CHECKED BY: SUBMITTED BY: CHIEF SECTION RECOMMENDED: CHIEF BRANCH APPROVED: APPROVED: DATE: SCALE: AS SHOWN SPEC. NO. DRAWING NUMBER SHEET

SAFETY PAYS

THIS PLAN ACCOMPANIES CONTRACT No.
MODIFICATION No.

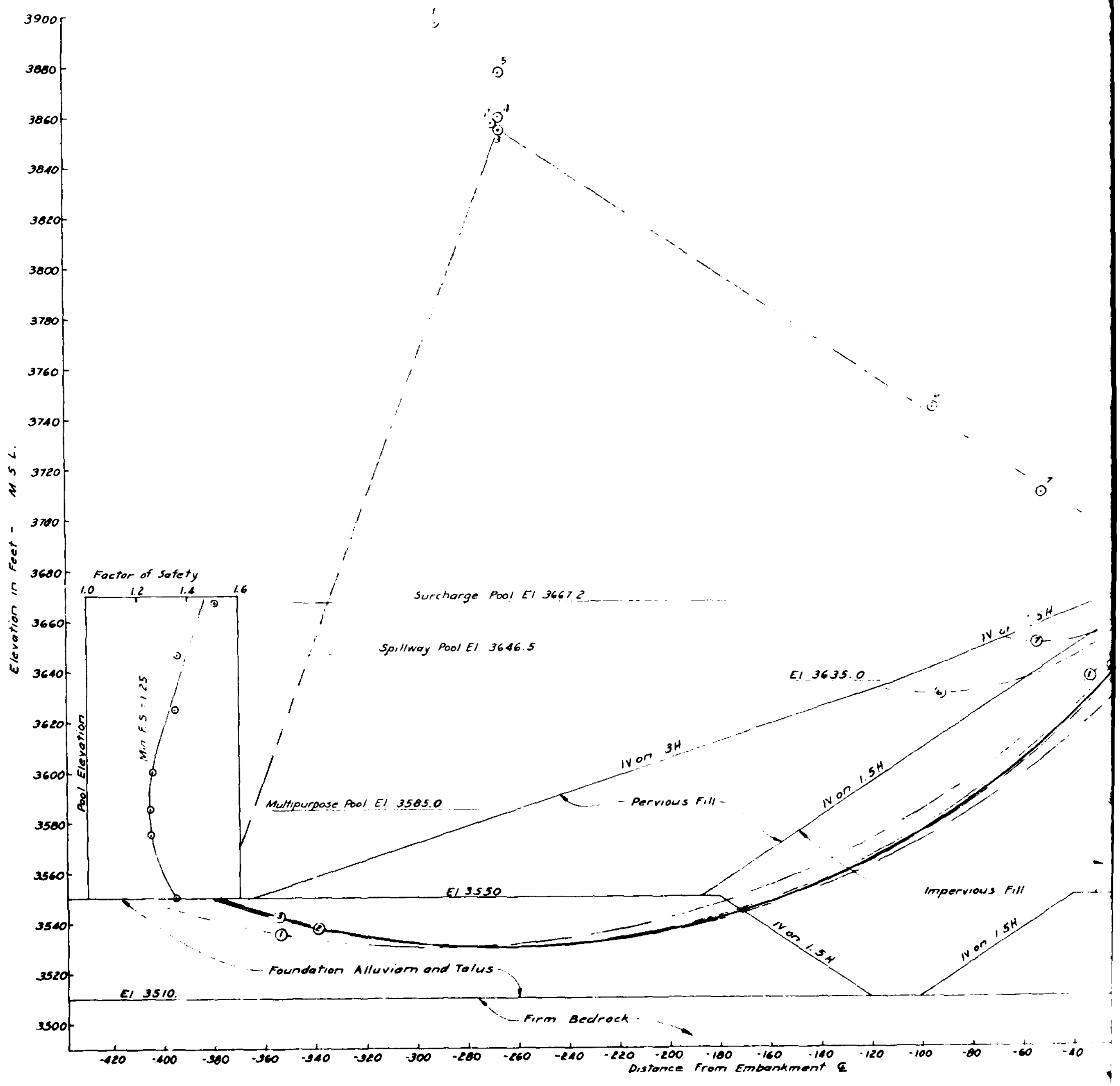


FIGURE 1
SCALE: 1 INCH = 20 FEET

Adopted Strengths

Material	Unit Weight (kcf)		Lower "S" Envelope			Upper "(R+S)/2" Envelope		
	γ Moist	γ Sat'd.	Coh (KSF)	Tan φ	φ (Deg.)	Coh (KSF)	Tan φ	φ (Deg.)
Pervious and Random fill	0.120	0.125	0	0.60	31.0°	0	0.60	31.0°
Impervious fill	0.120	0.125	0	0.50	26.6°	0.25	0.38	20.6°
Foundation Alluvium & Talus	0.120	0.125	0	0.50	26.6°	0.25	0.38	20.6°

FIGURE 2

Summary of Slip Circle Analysis

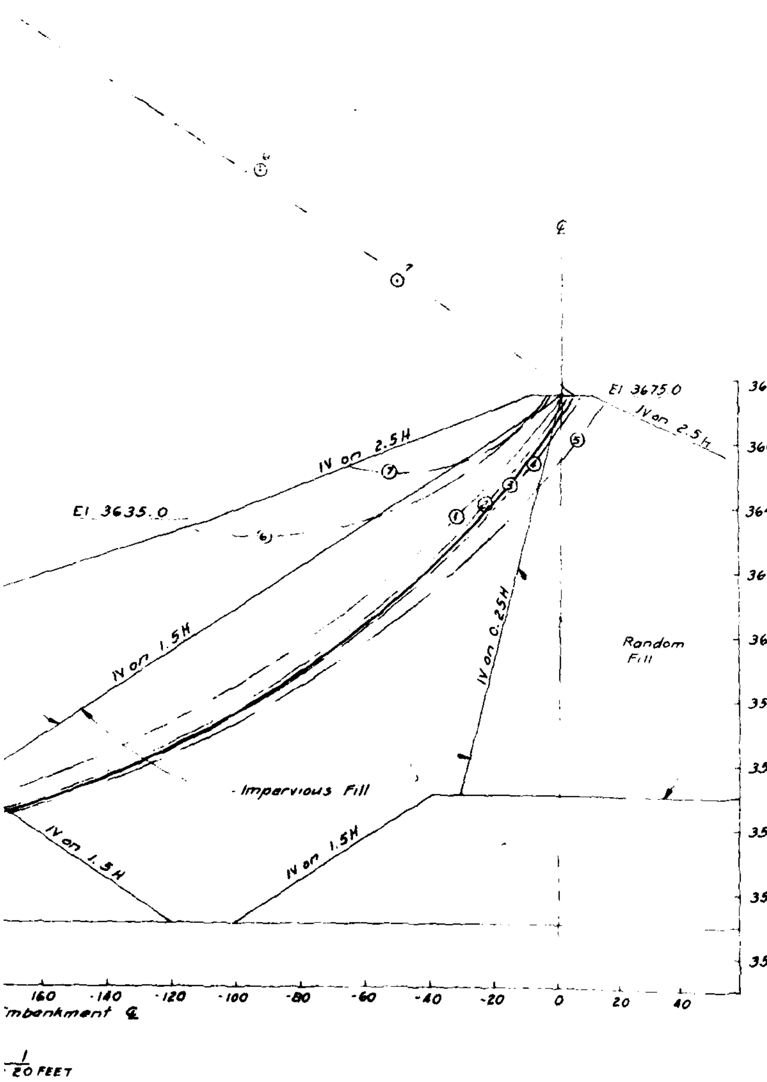
Partial Pool El.	Arc Base Elevation 3510	3530	3550	3570	3590	3610	3630	3650
3550	1.37	1.35 ①	1.71	1.72	1.7	1.67	1.61	
3575	1.32	1.25 ②	1.49	1.67	1.7	1.67	1.61	
3585	1.32	* 1.25 ③	1.42	1.53	1.7	1.67	1.61	
3600	1.35	1.26 ④	1.39	1.42	1.55	1.67	1.61	
3625	1.47	1.35 ⑤	1.49	1.44	1.40	1.43	1.61	
3646.5	1.61	1.47	1.61	1.56	1.53	1.42	1.36 ⑥	
3667.2	1.74	1.58	1.74	1.71	1.72	1.65	1.53	1.51 ⑦

FIGURE 3

Summary of Critical Arc Data

Partial Pool Elevation	Critical Arc Number	Arc Base Elev.	Coordinates of Arc Centers Horizontal	Vertical	Factor of Safety
3550	1	3530	-290.6	3897.3	1.35
3575	2	3530	-268.6	3857.3	1.25
3585	3	3530	-265.7	3854.4	1.25 *
3600	4	3530	-265.9	3859.8	1.26
3625	5	3530	-265.5	3877.3	1.35
3646.5	6	3630	- 94.7	3743.5	1.36
3667.2	7	3650	- 51.6	3709.9	1.51

FIGURE 4



Notes:

1. In Figure 3 the factors of safety above and to the right of the heavy line are not influenced by that particular pool elevation. These values have not been considered in evaluating the critical factor of safety.
2. Factors of safety in Figure 3 appended with a number appear in Figure 4 with the appended number as the critical arc number. This same number is used in Figure 1 to denote arc centers and arcs.
3. * Denotes lowest factor of safety.
4. Required factor of safety for Partial Pool Case without considering earthquake conditions is 1.5 and with earthquake considerations the required factor of safety is 1.0. Actual factors of safety were found to be 1.25 without earthquake and 1.03 with earthquake.
5. For hand run computations of the critical arc see Plate E-4.

THIS DRAWING HAS BEEN REDUCED TO THREE-EIGHTHS THE ORIGINAL SCALE.

SAFETY PAYS

REVISIONS

U. S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA

FALL RIVER BASIN, S.D.
COLD BROOK LAKE

STABILITY RE-EVALUATION
PARTIAL POOL CASE
(COMPUTER SUMMARY)

THIS PLAN ACCOMPANIES CONTRACT No.
MODIFICATION No.

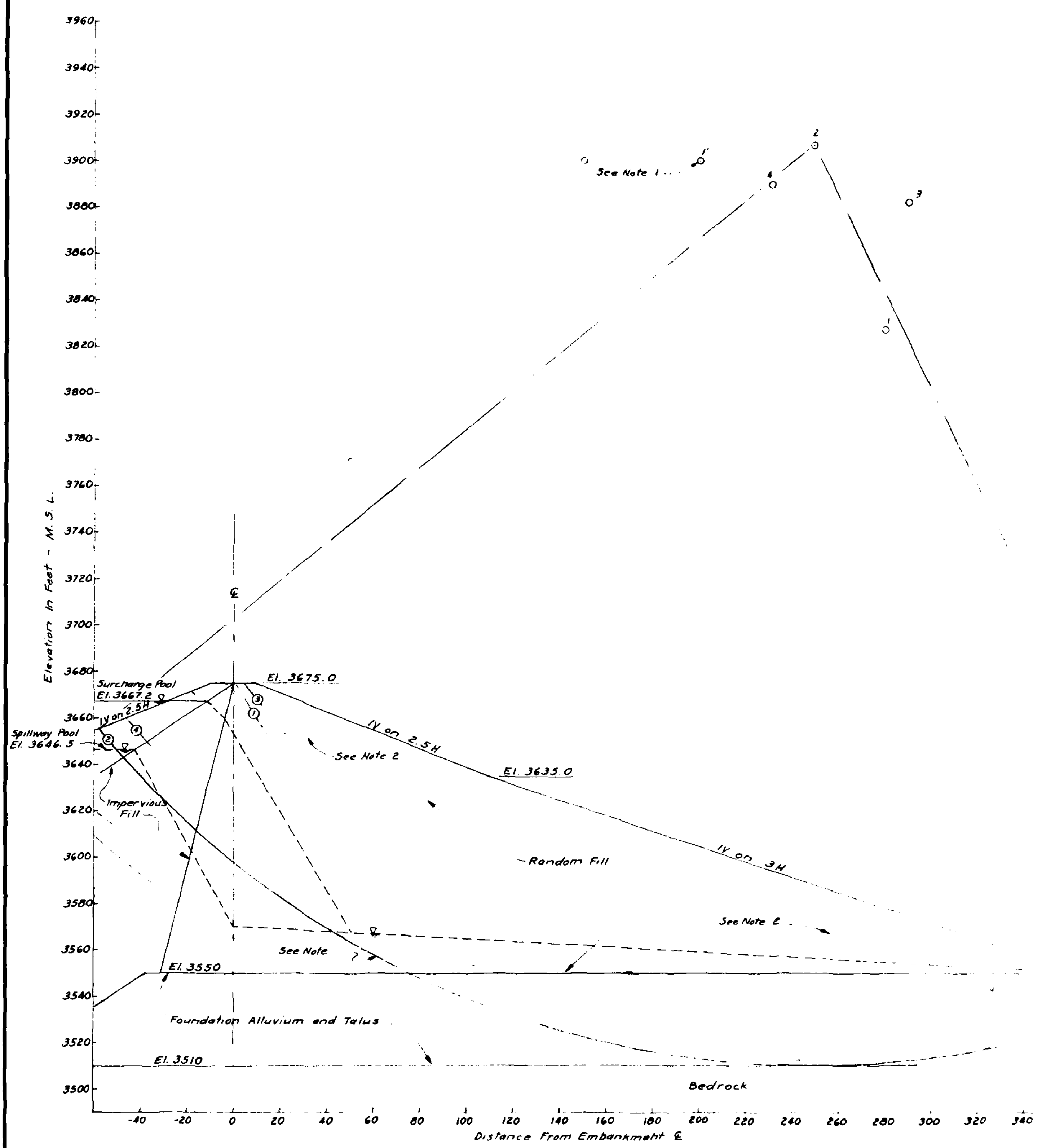
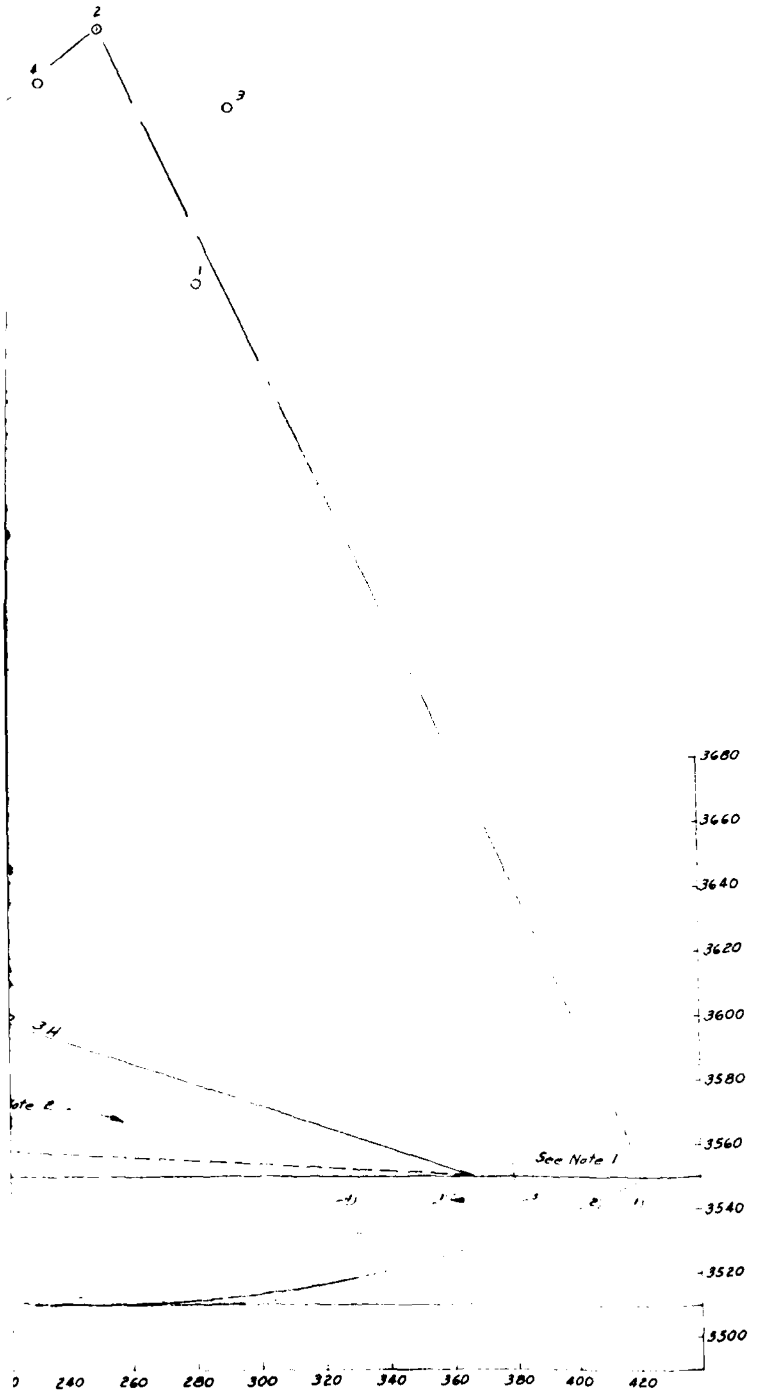


FIGURE 1

SCALE: 1 INCH = 20 FEET



Adopted Strengths								
Material	Unit Weight (kcf)		Lower "S" Envelope			Upper "(R+S)/2" Envelope		
	γ Moist	γ Sat'd	Coh (KSF)	Tan ϕ	ϕ (deg)	Coh (KSF)	Tan ϕ	ϕ (deg)
Pervious and Random Fill	0.120	0.125	0	0.60	31.0°	0	0.60	31.0°
Impervious Fill	0.120	0.125	0	0.50	26.6°	0.25	0.38	20.6°
Foundation Alluvium & Talus	0.120	0.125	0	0.50	26.6°	0.25	0.38	20.6°

FIGURE 2

Summary of Critical Arcs					
Arc Number	Arc Base Elevation	Coordinates of Arc Center		Factor of Safety	
		Horizontal	Vertical	Spillway Pool	Surcharge Pool
1	3510	279.4	3827.5	1.45	—
2	3510	249.0	3907.0	—	1.38
3	3530	289.5	3882.3	1.52	—
4	3530	230.4	3890.0	—	1.55

FIGURE 3

Notes:

1. Although the location of the critical arc for the spillway pool is not affected by that pool, the initial arc centers were selected so that the arcs passed thru the line of seepage. This is illustrated for the critical case, arc 1 by presenting its first trial arc 1' having a F.S. = 1.58. This was typical of all other arcs for the spillway pool.

2. These circles represent the range in elevations for which circles were run in the embankment. The resultant circles, with minimum factors of safety approached the infinite slope condition, giving factors of safety ranging from 1.7 to 1.5 depending on what part of the slope was being analyzed.

3. For manual analysis of the critical arc, see Plate E-6 .

4. The critical arc for the spillway pool was arc number 1. Its factor of safety without earthquake conditions was 1.45 with 1.5 being required. With earthquake conditions the factor of safety is 1.21 with 1.0 required. The critical arc for the surcharge pool was arc number 2. It had a factor of safety of 1.38 with 1.4 being required.

THIS DRAWING HAS BEEN REDUCED TO THREE-EIGHTHS THE ORIGINAL SCALE.

REVISIONS

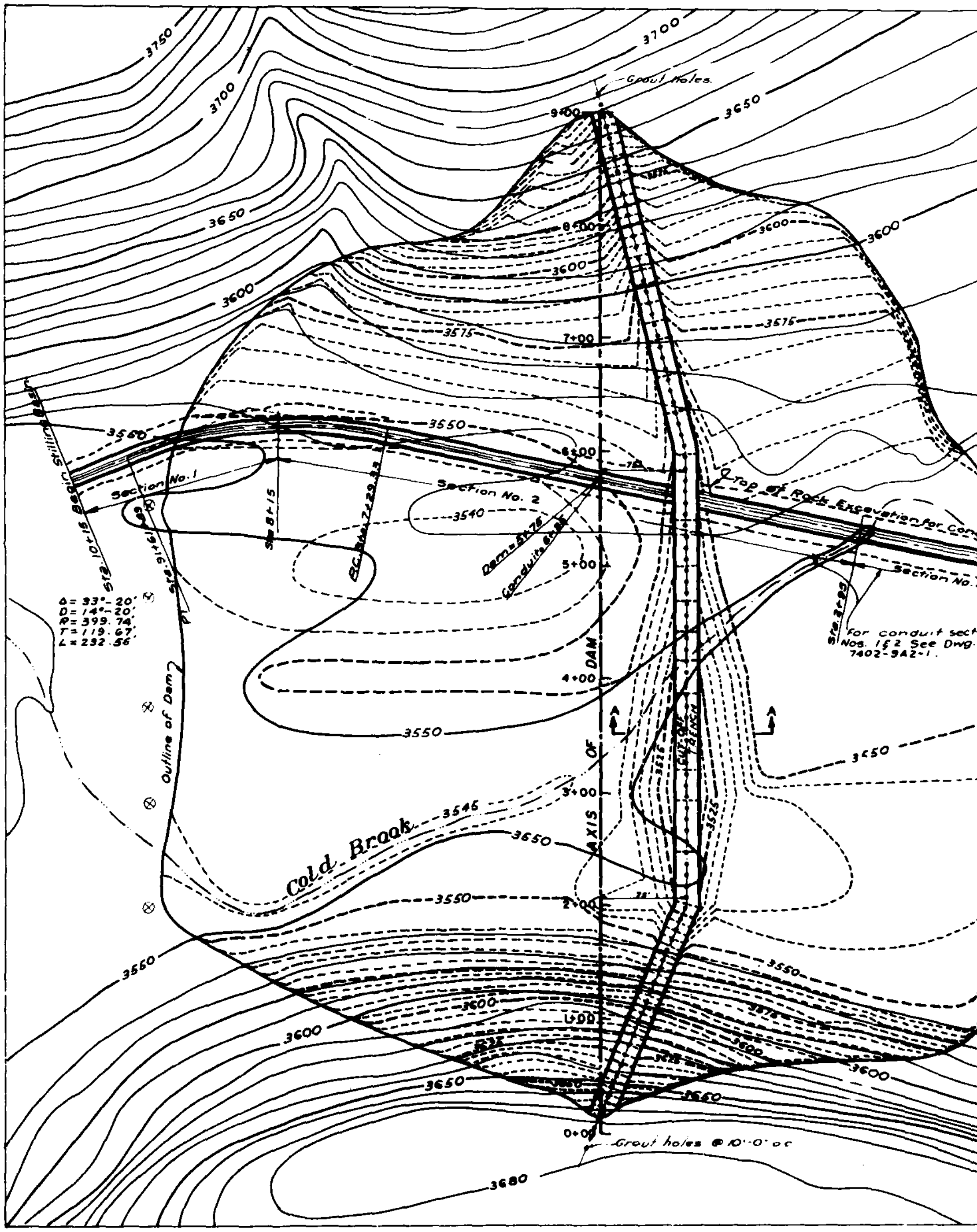
U. S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA

FALL RIVER BASIN, S.D.
COLD BROOK LAKE
STABILITY RE-EVALUATION
STEADY SEEPAGE CASE
(COMPUTER SUMMARY)

SCALE AS SHOWN

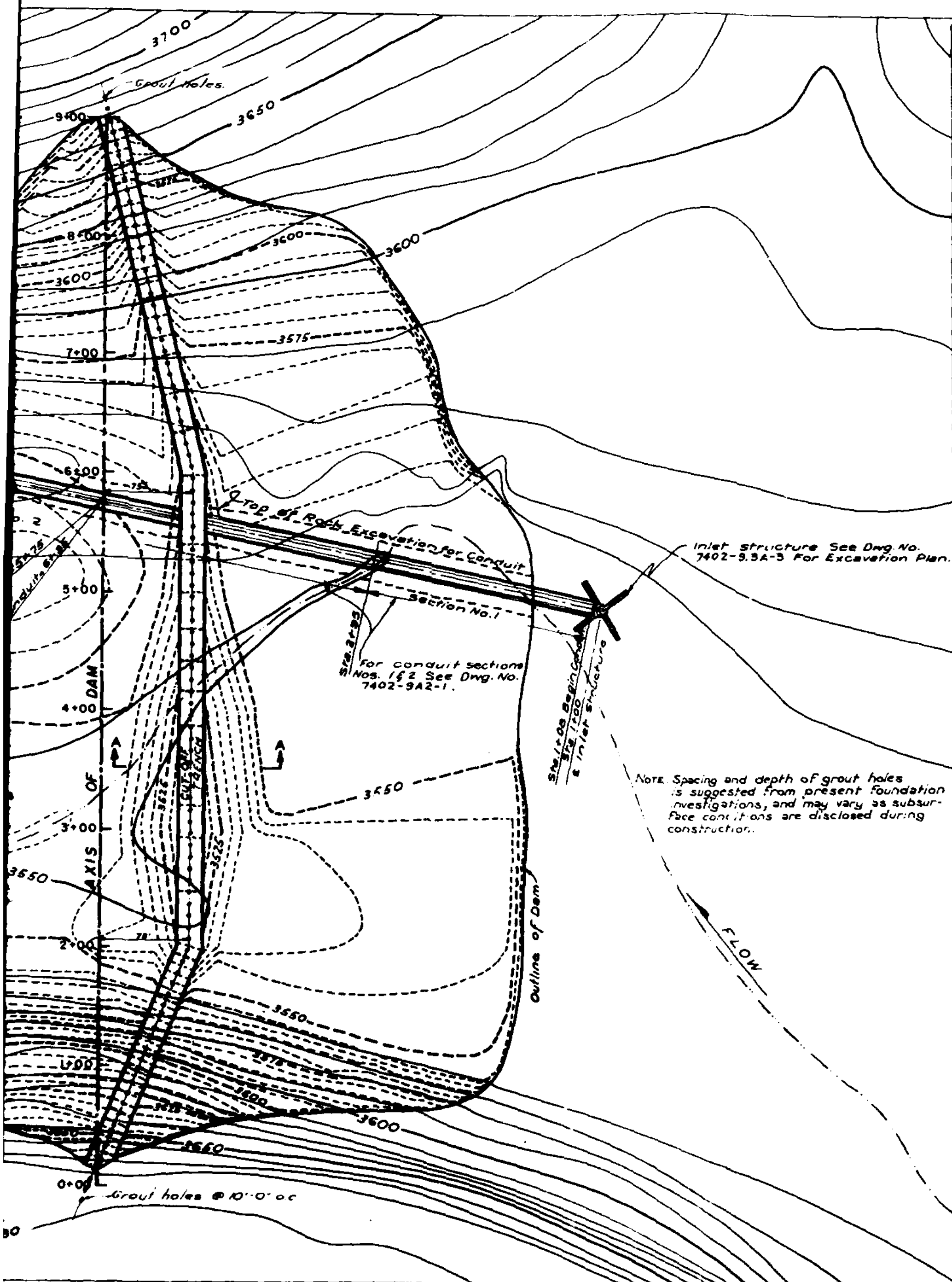
THIS PLAN ACCOMPANIES CONTRACT NO.
MODIFICATION NO.

CORPS OF ENGINEERS

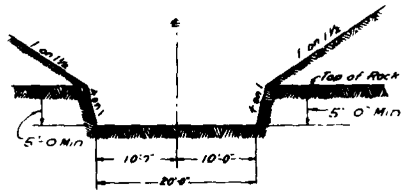


THIS DRAWING HAS BEEN REDUCED TO THREE-EIGHTHS THE ORIGINAL SCALE.

U. S. ARMY



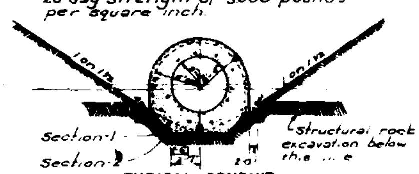
NOTE "A" In the event that removal of protection stone materials from Borrow Area "B" discloses desirability of additional pressure grouting between the left abutment and the Spillway Channel, additional grout holes shall be drilled and grouted as directed by the Contracting Officer, at the applicable contract unit prices.



SECTION A-A

Typical Section of Cutoff Trench
No Scale

The concrete conduit structure is designed for a minimum 28 day strength of 4000 pounds per square inch. All other concrete structures are designed for a minimum 28 day strength of 3000 pounds per square inch.



TYPICAL CONDUIT SECTIONS 1 & 2

No Scale

Note: Grout holes will be spaced on 10 foot centers on ℄ of cutoff trench. Line of holes will extend the full length of the cutoff trench plus 20' on each end, for the primary holes. Any suceeding holes will be placed as directed.

The excavation contours shown are estimated and will be finally determined from conditions of the foundations as disclosed at the time the excavation is made.

Exploratory holes in cutoff trench shall be pressure grouted. Exploratory holes on conduit center line shall be filled with grout. For location and profile of these exploratory holes, see Dwgs No 7402-9A5-1 and 7402-9A6-2A respectively.

LEGEND

Original Ground ————
Finished Contours - - - - - -
(Foundation after Stripping)
Grout Holes . . . . . .

FALL RIVER BASIN

COLD BROOK DAM

COLD BROOK, SO DAK

FOUNDATION TREATMENT & GROUTING

IN 6 SHEETS — GRAPHIC SCALE — SHEET NO 2

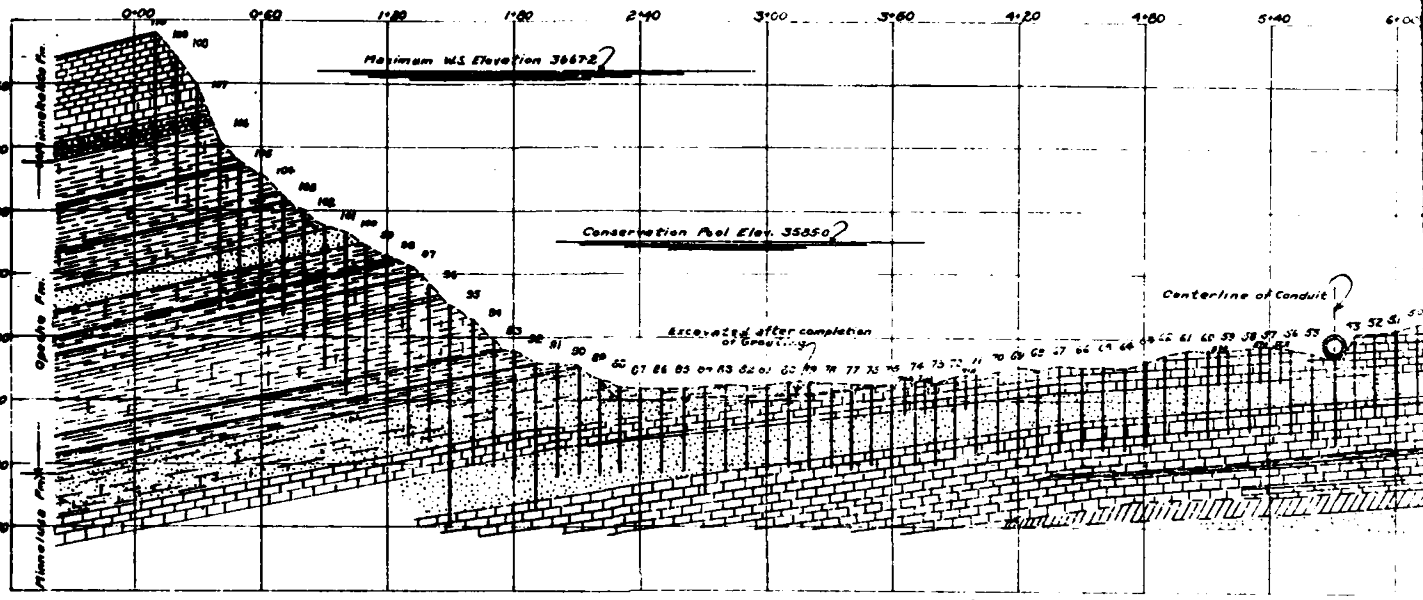
PORT PECK DISTRICT, FORT PECK, MONTANA — SEPTEMBER 1, 1949

7402-9A1-2

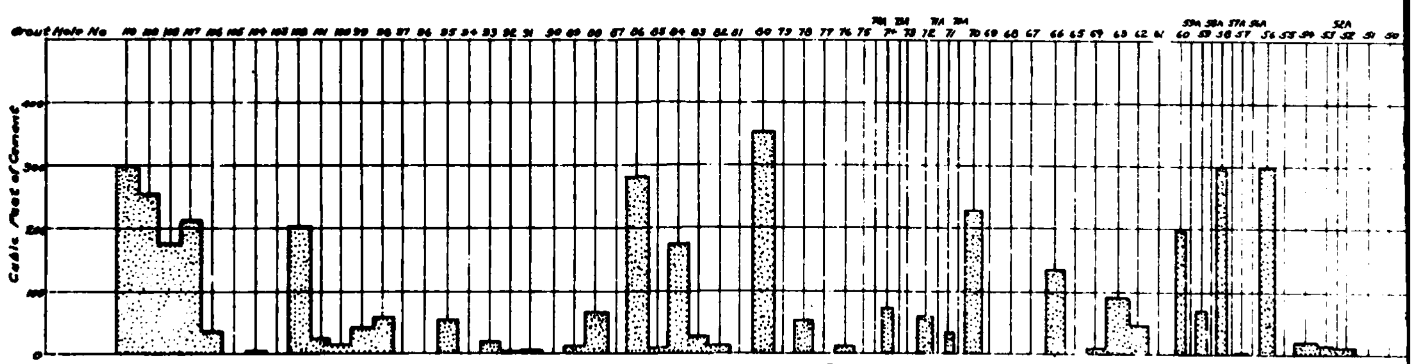
THIS DRAWING HAS BEEN REDUCED TO THREE-EIGHTHS THE ORIGINAL SCALE.

No.	Description	Date	Appr.
4.	Note on foundation investigation added	6-26-50	
3	Grouting Note 'A' added	6-19-50	
2	Concrete and grout hole notes revised	3-22-50	
1.	Grout holes added ℄ note revised.	3-22-50	

REVISIONS



Geological Section Along Centerline of Cutoff Trench
Showing Location and Depth of Grout Holes and Final Excavation Line
Section A-A

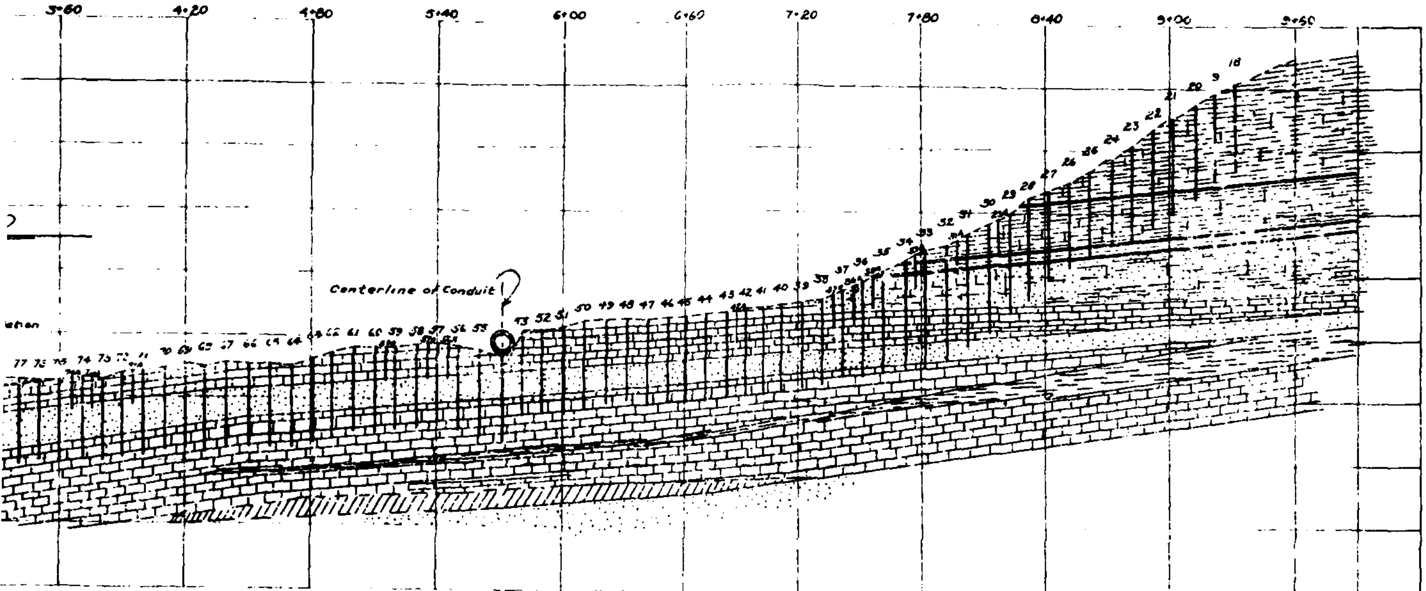


Bargraph Showing Cubic Feet of Cement Injected in Each Grout Hole

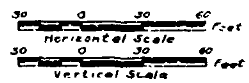
LEGEND

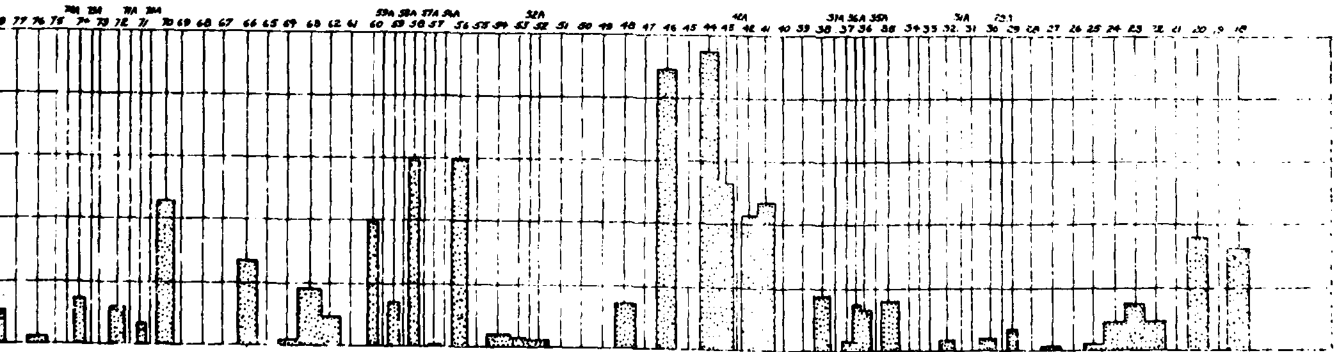
- Limestone
- Argillaceous Limestone
- Fine grained Buff and Orange Sandstones
- Jointed, Shaley and Limey Sandstones
- Red, Soft, Jointed Shales
- Solution Channel with Redeposited Limey Clay
- Final Excavation Line

EMB



Geological Section Along Centerline of Cutoff Trench
Showing Location and Depth of Grout Holes and Final Excavation Line
Section A-A





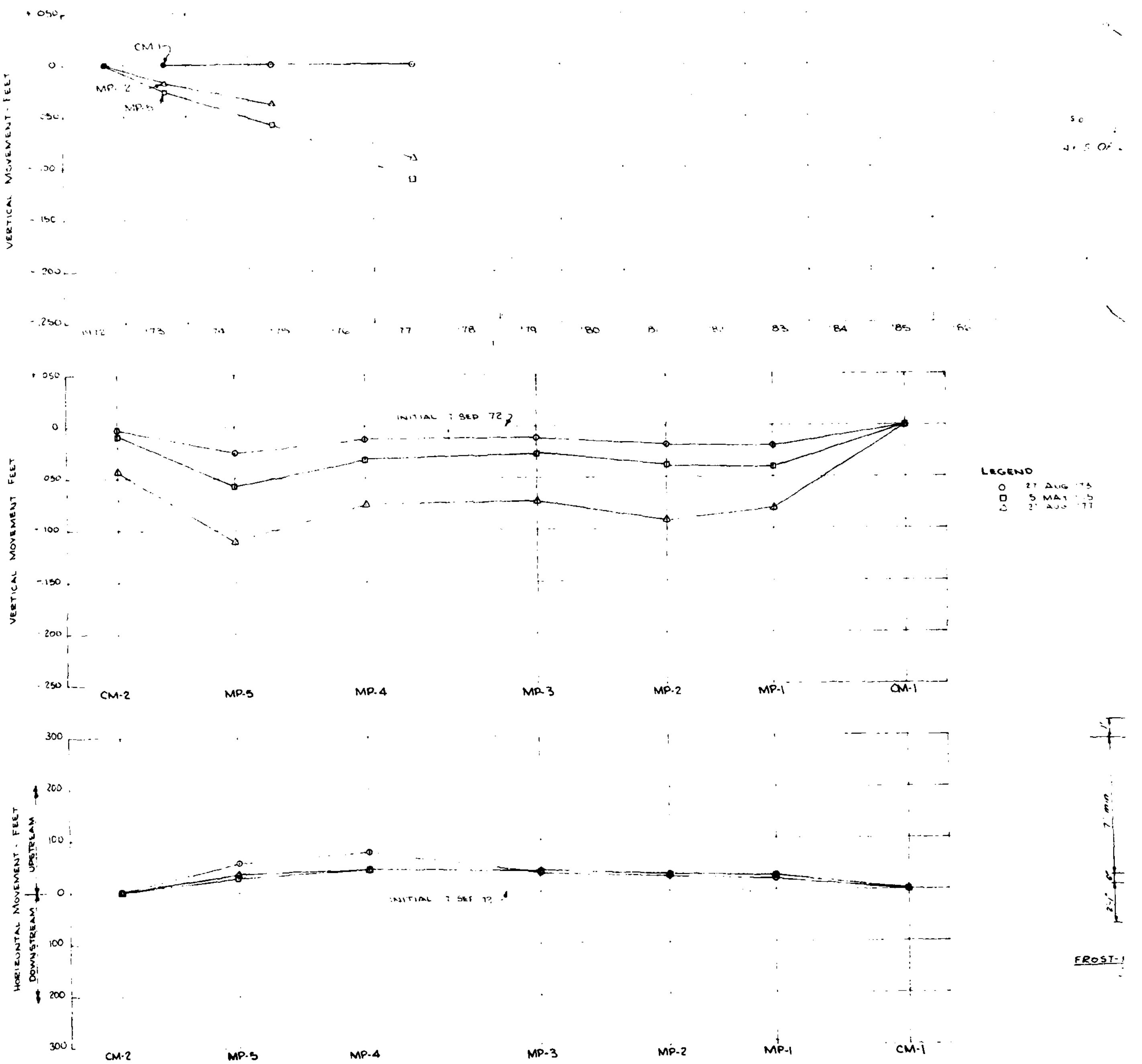
Bargraph Showing Cubic Feet of Cement Injected in Each Grout Hole

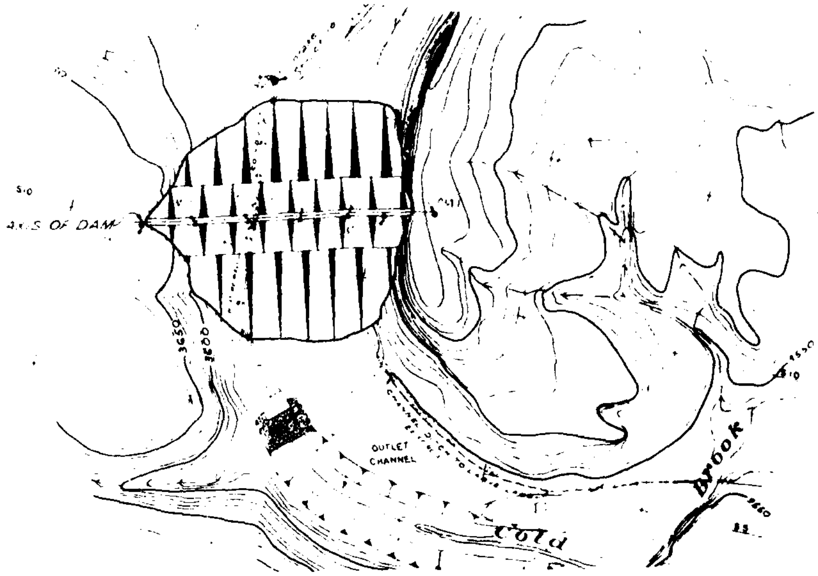
Note

For Plan Showing Location of Cutoff Trench Refer to Plate
Total Cement injected Entire Cutoff Curtain 6786.7 Sacks
Total drilling entire Cutoff Curtain 4666.8 Lin Ft.

NO	DESCRIPTION	DATE	APP'D
	REVISIONS		

FALL RIVER BASIN
COLD BROOK DAM
HOT SPRINGS, SOUTH DAKOTA
FOUNDATION REPORT
CUTOFF CURTAIN
IN 4 SHEETS — SCALE AS SHOWN — SHEET NO 3
FORT PECK DISTRICT, FORT PECK, MONTANA - JANUARY 1934
DRAWN J.B.K. TRACED J.B.K. CHECKED G.Y.A.
7402-9.1-7

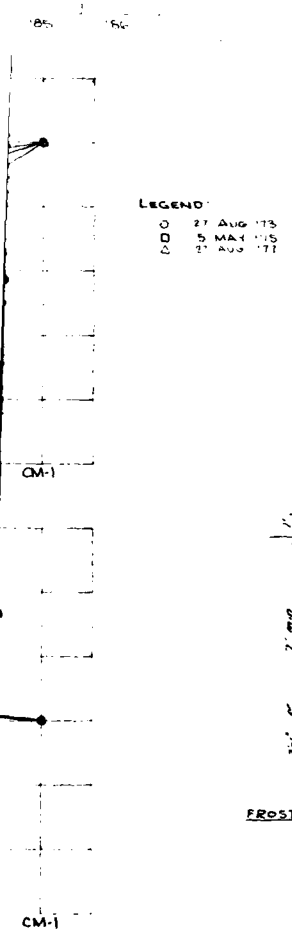

VERTICAL MOVEMENT - FEET
CM-1
MP-2
MP-5
INITIAL 7 SEP 72
LEGEND
27 AUG 73
5 MAY 75
27 AUG 77
CM-2
MP-5
MP-4
MP-3
MP-2
MP-1
CM-1
HORIZONTAL MOVEMENT - FEET
UPSTREAM
DOWNSTREAM
FROST-

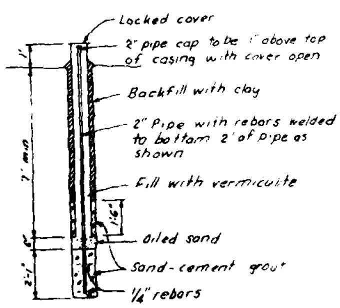


GENERAL PLAN

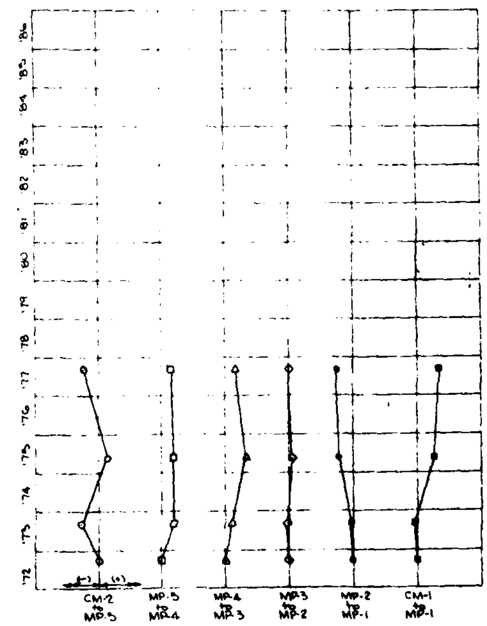
SCALE 200 100 0 200 400 FEET

Legend
● CM-1 Control Marker
▲ MP-1 Movement Point





FROST-FREE MOVEMENT MARKERS
TYPICAL INSTALLATION



HORIZONTAL MOVEMENT - FEET
SCALE: 1" = .100'

DATE	DESCRIPTION	MARK	APPROVED

REVISIONS

U. S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA

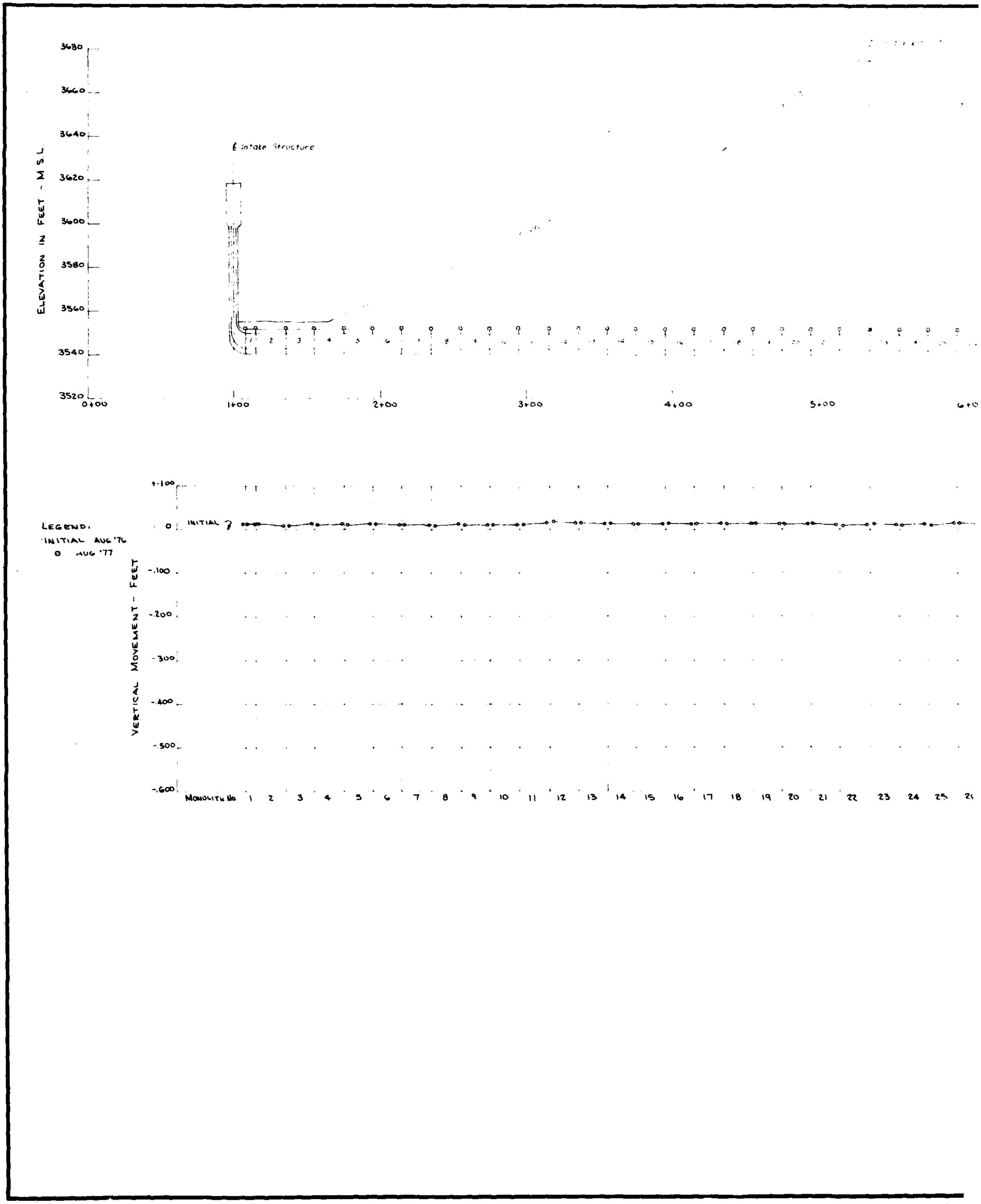
FALL RIVER BASIN, SOUTH DAKOTA
COLD BROOK DAM
EMBANKMENT
CREST MOVEMENT POINTS
HORIZONTAL & VERTICAL MOVEMENT

THIS DRAWING HAS BEEN REDUCED TO ... THE ORIGINAL SCALE.

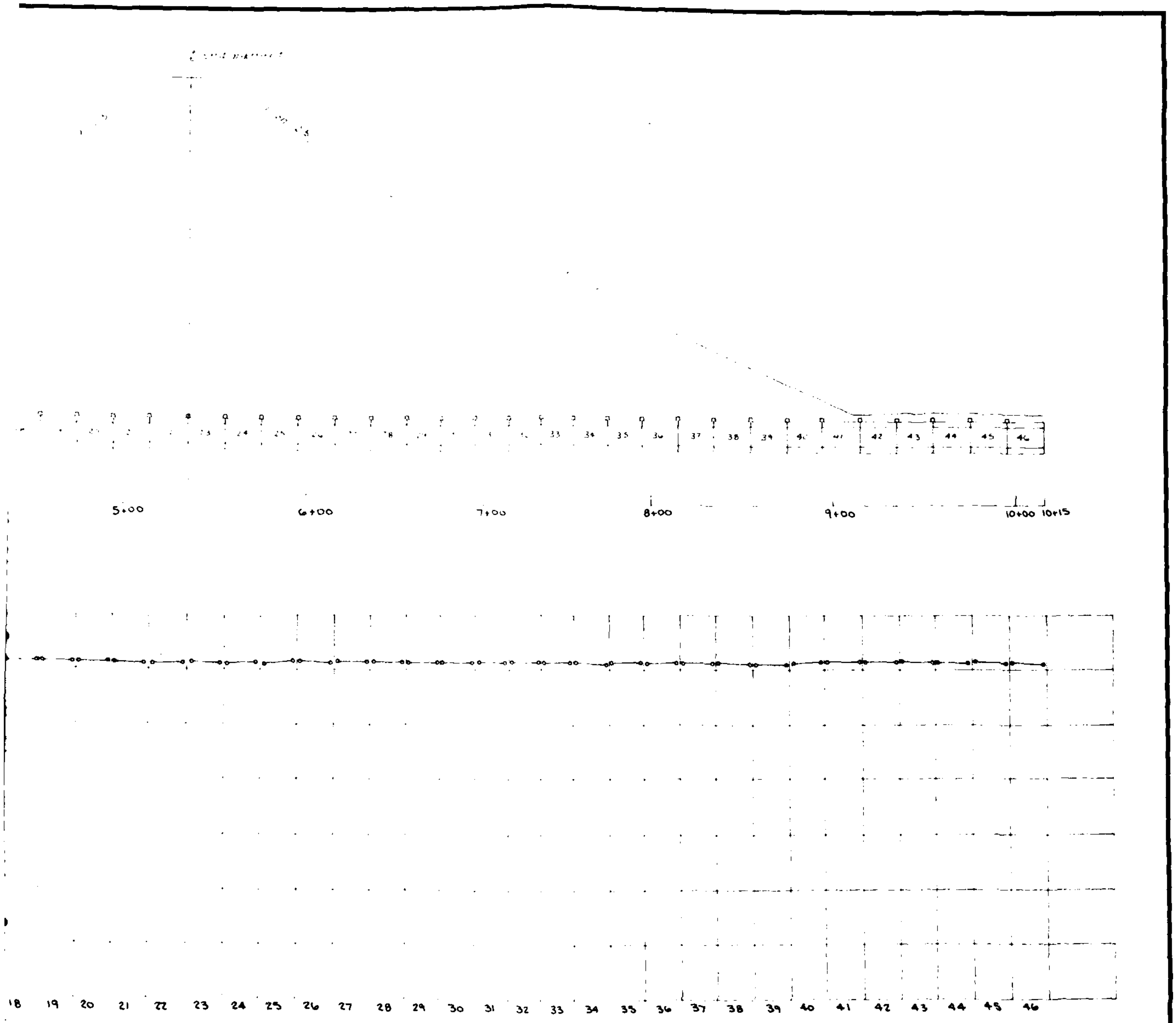
SAFETY PAYS

THIS PLAN ACCOMPANIES CONTRACT NO.
MODIFICATION NO.

SCALE AS SHOWN



ELEVATION IN FEET - M S L
3680
3660
3640
3620
3600
3580
3560
3540
3520
0+00
1+00
2+00
3+00
4+00
5+00
℄ Intake Structure
LEGEND:
INITIAL AUG '76
o AUG '77
VERTICAL MOVEMENT - FEET
+.100
0
-.100
-.200
-.300
-.400
-.500
-.600
INITIAL
MONOLITH No 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25



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DATE	DESCRIPTION	MADE	APPR'D

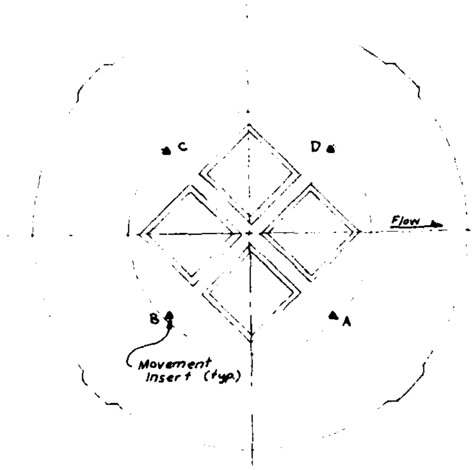
REVISIONS

U. S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA

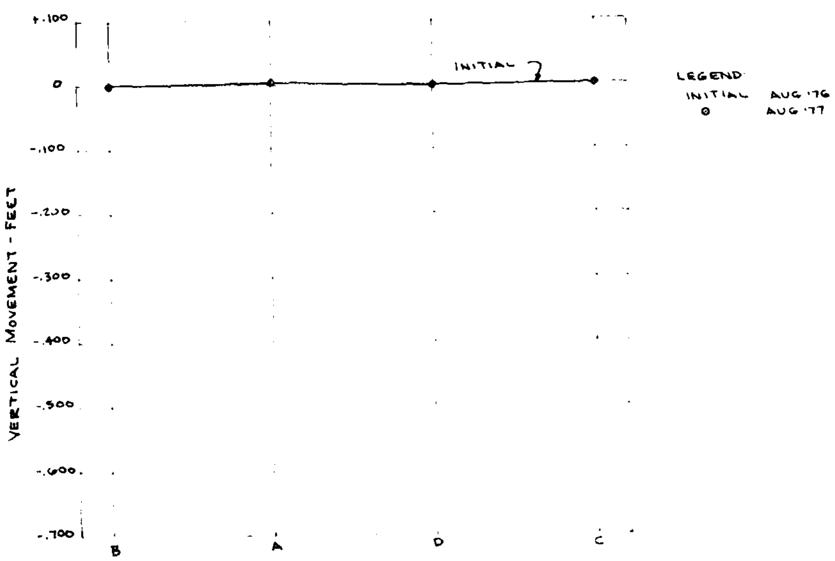
FALL RIVER BASIN, SOUTH DAKOTA
COLD BROOK DAM
OUTLET WORKS
CONDUIT - VERTICAL MOVEMENT

SCALE AS SHOWN

THIS PLAN ACCOMPANIES CONTRACT No.
MODIFICATION No.



INTAKE STRUCTURE
PLAN OF TOP SLAB
N.T.S.



THIS DRAWING HAS BEEN REDUCED TO
THREE-EIGHTHS THE ORIGINAL SCALE.

DATE	DESCRIPTION	MARK	APPR'D

REVISIONS

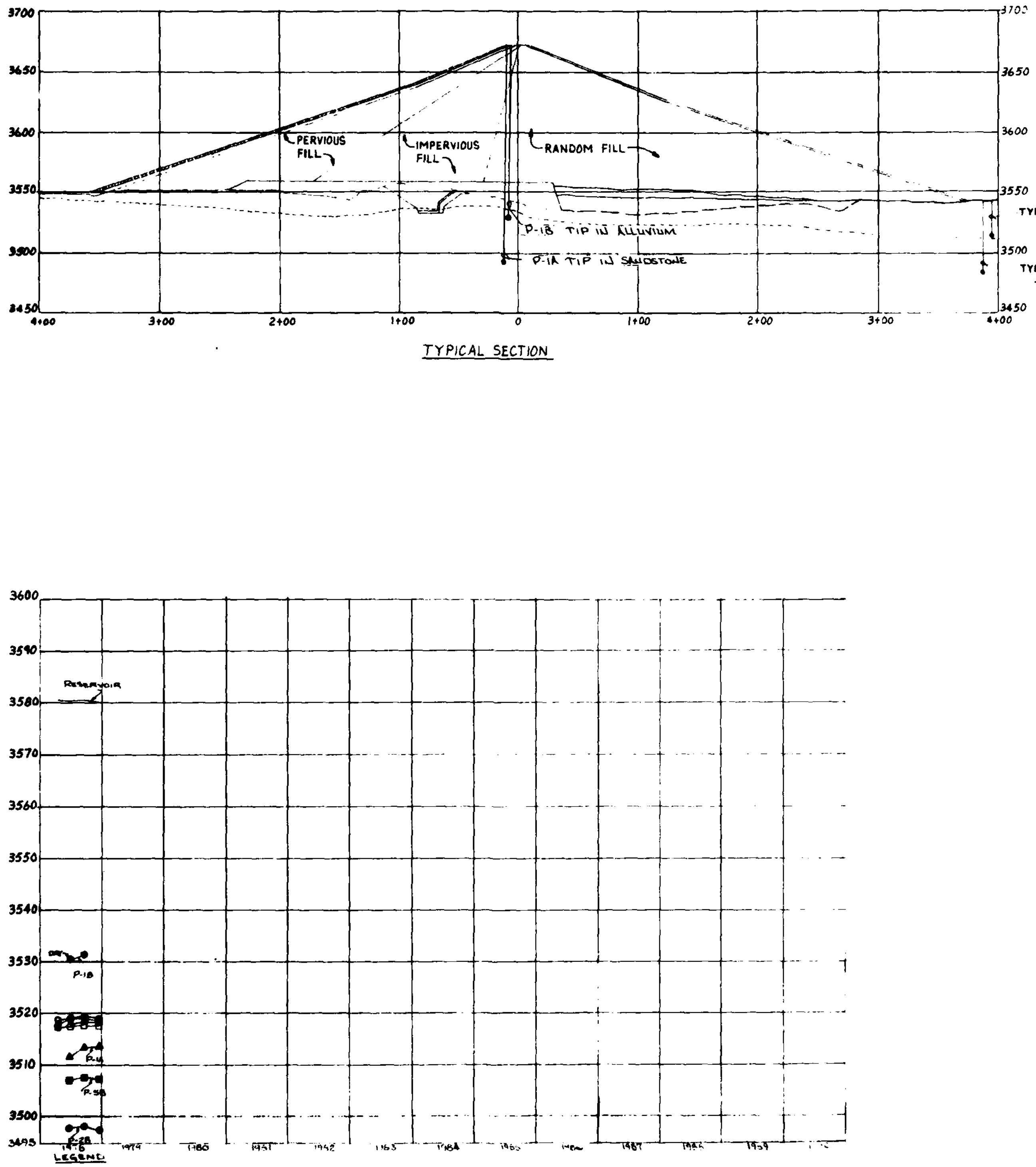
U. S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA

FALL RIVER BASIN, SOUTH DAKOTA
COLD BROOK DAM
OUTLET WORKS
INTAKE STRUCTURE - VERTICAL MOVEMENT

SCALE: AS SHOWN

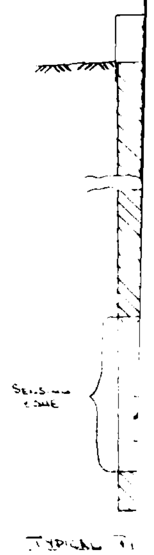
SAFETY PAYS

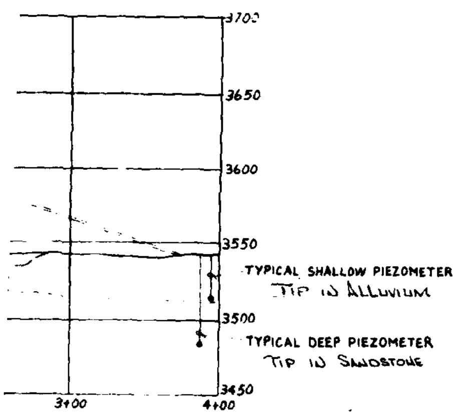
THIS PLAN ACCOMPANIES CONTRACT No.
MODIFICATION No.

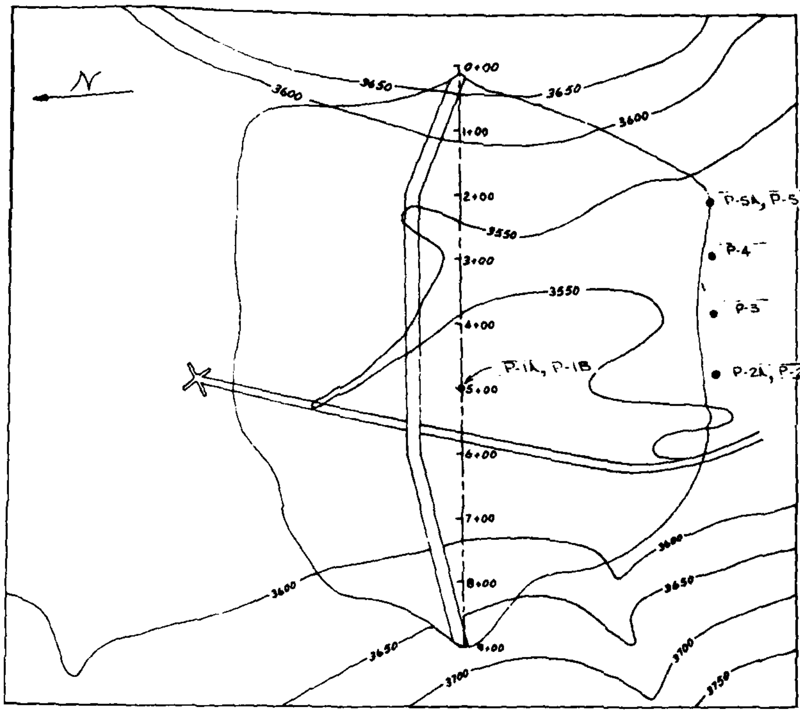


LEGEND

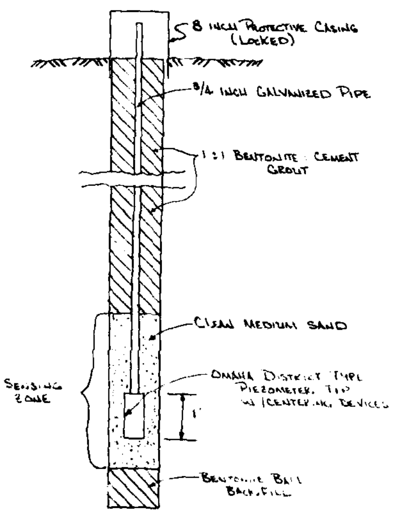
- P-2B (DEEP)
- P-2A (SHALLOW)
- P-3
- P-4
- P-5A (SHALLOW)
- P-5B (DEEP)
- P-1A HIGH (DEEP)
- P-1B LOW (SHALLOW)







LOCATION PLAN



TYPICAL PIEZOMETER INSTALLATION

THIS DRAWING HAS BEEN REDUCED TO THREE-EIGHTHS THE ORIGINAL SCALE.

DATE	DESCRIPTION	MADE	APPR'D
	REVISIONS		

U. S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA

FALL RIVER BASIN, SOUTH DAKOTA

COLD BROOK DAM

Piezometers

DESIGNED BY:
DRAWN BY:
CHECKED BY:
SUBMITTED BY:
APPROVED:
DATE:
SCALE: AS SHOWN
SPEC. NO.

THIS PLAN ACCOMPANIES CONTRACT NO.
MODIFICATION NO.